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Emergence of a Telco Cloud platform: paradigm, cost structure and strategic implications

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ABSTRACT OF THE
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Telecommunications providers are facing pressures to adjust their production models while markets are changing and cloud service models are spreading to their business areas. The Telco Cloud platform model was designed to respond to these forces. The Telco Cloud is a cloud computing platform that is intended for virtualized network functions. The platform meets requirements of the telecommunications market and regulations. A cloud based production model is a new concept in the context of telecommunications services, hence, the field of the Telco Cloud is not yet well researched area. Furthermore, the cost structure and strategic implications of the Telco Cloud platform are still poorly understood. This empirical research uses a single company single case study approach to examine the Telco Cloud paradigm, cost structures, processes and strategic implications by using qualitative and explorative analysis methods. The data collection was done using literature review and interviews. The literature review revealed that very little research is done on the field. Furthermore, eight semi-structured interviews were carried out with persons in managerial position. These experts were working in the Telco Cloud project in the case company and had deep telecommunications industry knowledge. The results of the study indicate that the Telco Cloud benefits improved investment efficiency due to a server virtualization and consolidation compared to the traditional platform model; high level of automation and server utilization are key features to achieve benefits; increased personnel costs in the software development and communication are prolonging the break-even point; and the platform takes advantage of the network effects and the Telco Cloud eventually shall improve significantly operator's cost efficiency. This research aims to provide a base for further research. Furthermore, the research contributes the application on-boarding process that can be used for managing the complexity of a Telco Cloud deployment.

Keywords: Telco Cloud, Cost structure, Carrier Cloud

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Teleoperaattorit joutuvat tarkastelemaan tuotantotapojaan pilvipalveluiden levittäytyessä myös teletoiminnan piiriin. Teleoperaattorin pilvi voidaan nähdä vastauksena muutospaineeseen. Teleoperaattorin pilvi on pilvilaskentapohjainen palvelualusta, joka on tarkoitettu verkkotoiminnallisuuksien virtualisointiin ja se täyttää markkinan ja regulaation asettamat vaatimukset. Pilvituotantomalli on uusi konsepti telepalveluiden alueella. Lisäksi Teleoperaattorin pilvi-mallia ei ole vielä juurikaan tutkittu. Lisäksi teleoperaattorin pilvi-mallin kustannusrakenne ja strategiset seuraamukset ovat vielä huonosti ymmärrettyjä. Tämän opinnäytetyön yhteydessä suoritettiin kvalitatiivinen ja eksploratiivinen tutkimus yksittäisen tapaustutkimuksen avulla. Tutkimuskohteena oli Teleoperaattorin pilvi käsitteenä, sen kustannusrakenne ja strategiset seuraukset. Tiedonkeruu suoritettiin kirjallisuustutkimuksen ja haastatteluiden avulla. Kirjallisuustutkimus osoitti, että aluetta on tutkittu erittäin vähän ja vallitsevaa paradigmaa ei ole vielä syntynyt. Tutkimuksen empiirisessä osuudessa suoritettiin kahdeksan puolistrukturoitua haastattelua alan asiantuntijoiden kanssa. Tutkimuksen tulokset osoittavat, että Teleoperaattorin pilvi mahdollistaa palvelinvirtualisoinnin ja konsolidaation avulla tehostumista investointien käytössä verrattuna perinteiseen palvelualustamalliin; korkea automaatioaste ja palvelinten korkea kuormitusaste ovat edellytyksiä tehostumisen saavuttamiseksi; kasvavat henkilöstökulut ohjelmistokehityksessä ja sidosryhmäkommunikoinnissa pitkittävät kannattavuusrajan saavuttamista; ja toimija voi parantaa kustannustehokkuuttaan merkittävästi konsolidoimalla palveluitaan Teleoperaattorin pilvi-alustaan. Tämän tutkimuksen tarkoituksena on luoda pohjaa tulevalle tutkimukselle. Lisäksi tutkimuksen tulokset tarjoavat prosessin sovellusten siirtämiseksi Teleoperaattorin pilveen.

Avainsanat: Teleoperaattorin pilvi, Kustannusrakenne, Pilvilaskenta

Preface

The telecommunications industry has changed quite dramatically since my first touch with the networking area back in the 1997. Emergence of Internet, mobile communications and cloud services have changed our daily life radically. Many years in the telecommunications industry have been very educational for me. I consider it as a privilege that I have had an opportunity to follow such a magnificent change in our whole society. We are living exciting times.

During all those years I spent in Aalto University, I got all support I needed. I especially appreciate the effort made by the personnel of the Department of Communications and Networking. It has been a priviledged opportunity to get a multidisciplinary view to the fields of networking technologies, communications economics and strategic management during my academic studies. It have been great to see that Aalto University has been able to renew and transform to meet the needs of the modern science and industry.

This Master's Thesis was the last effort in my studies in Aalto University. The research process took seven months, from February to September 2015. I would like to thank several persons personally.

I thank my supervisor, Professor Heikki Hämmäinen, for all wisdom he gave me during the thesis process. All those great suggestions and questions steered the whole research to the better direction.

My scientific advisor, M.Sc. Nan Zhang, gave great tips and hints during the research process. I would like to thank her for improving the quality of the thesis. This thesis would be quite different without her help.

The Master's Thesis research was carried out in co-operation with the industry partner. The case company gave excellent opportunity to study this new phenomena. The case company gave all support I needed to carry out this research. I would like to thank my advisor M.Sc. Matti Swan in the case company. He was able to help me in the substance issues greatly and guided me to speak with the right people.

Furthermore, I thank all those persons that contributed this research. All comments from interviewees enabled me to carry out the analysis of phenomena which would be otherwise impossible to study. My thanks to the readers of my drafts. All those suggested changes made the thesis more useful.

Helsinki, 16.9.2015

Jarno Lähteenmäki

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Abbreviations

Abbreviation	Definition
ABC	Activity-Based Costing System
AMS	Application Management Services
API	Application Programming Interface
ARPU	Average Revenue Per Unit
BSC	Balanced Score Card
CAPEX	Capital Expenditure
CMDB	Configuration Management Database
COTS	Commercial Off-the-Shelf
CPU	Central Processing Unit
CSF	Critical Success Factor
DC	Data Centre
DC48V	48 Volt Direct Current Electricity Feed
EPC	Evolved Packet Core
ETSI	European Telecommunications Standards Institute
EU	European Union
FDC	Fully-Distributed Costing
FICORA	Finnish Communications Regulatory Authority
HA	High Availability
IaaS	Infrastructure as a Service
ICT	Information and Communication Technology
IEC	International Engineering Consortium
IEEE	Institute of Electrical and Electronics Engineers
IAS	International Accounting Standard
IFRS	International Financial Reporting Standard
IMS	IP Multimedia Subsystem
IoT	Internet of Things
IPR	Intellectual Property Rights
IPv6	Internet Protocol Version 6
ISO	International Organization for Standardization
IT	Information Technology
ITU	International Telecommunications Union
ITU-T	ITU Telecommunication Standardization Sector
KVM	Kernel-based Virtual Machine
LRIC	Long-Run Incremental Cost
LTE	Long Term Evolution
MME	Mobility Management Entity
MMS	Multimedia Messaging Service
MNO	Mobile Network Operator
MVNO	Mobile Virtual Network Operator
MWh	Mega Watt Hours
NFV	Network Function Virtualization
OPEX	Operating Expenditure
OSS	Operations Support System
OTT	Over The Top

Abbreviation	Definition
PUE	Power Usage Effectiveness
QA	Quality Assurance
QEMU	Quick Emulator
RAN	Radio Access Network
R&D	Research and Development
RE	Requirement Engineering
SDN	Software Defined Networking
SMS	Short Messaging Service
SRIC	Short-Run Incremental Cost
TL1	Importance Class 1 Facility
UPS	Uninterruptible Power System
VAS	Value-Added Services
VNF	Virtualized Network Function
WAN	Wide Area Network

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1 Introduction

The telecommunications service market has a history of more than 200 years [1]. However, paradigms have changed in last 50 years more than in the early life. Privatization of government owned telecommunications units, digitalization and mobile communications are just a few of those radical changes on the market [2]. Nowadays, operators are suffering from decreasing revenues [3], saturating markets [4] and increasing pace of new technologies [5]. Recent development in technologies have changed modern business models and every persons' daily life on earth. Concepts such as the Internet, cloud computing and internet of things are bringing new challenges to the table. Cloud computing and service programmability are forcing also the telecommunications industry to react to these steams. The Telco Cloud can be seen as a response to it.

Development of the new concept called Telco Cloud started in early 2010s. Standardization bodies, commercial vendors and operators jumped into the development bandwagon. However, small number of published scientific papers indicate that scholars have not yet found this field of research. Several areas exist that need more thorough understanding before incumbents can rely on this new concept. Furthermore, it takes time before the concept settles and it can be considered that paradigm has formed. For example, a transition to software based approach indicates that the regulation has to change, thus, discussion between operators and national regulatory authorities should be started.

Traditionally the telecommunications service production has based on service dedicated platforms and tight integration with vendors. This same model does not apply as such in the Telco Cloud concept due to modular software based approach. Instead, operators need overall capability to manage wide network of vendors. To carry out this successfully, operators need capabilities to analyse costs related to the platform and to introduce new applications into the shared platform.

The economical problem that telecommunication operators are facing is declining per user revenues due to the fact that modern internet based services are substituting traditional services [6]. Furthermore, growing use of cellular data [7, p.13] is increasing especially capital expenditures (CAPEX) but also operational expenditures (OPEX), thus, reducing profits. At the same time, service price erosion of the telecommunications services [7, p.14] forces operators to introduce new enhanced over-the-top (OTT) and value-added-services (VAS) to the market. This initially increases research and development (R&D) costs and eventually also revenues.

The major technological obstacles are related to the network service development and the platform life-cycle management. Service development has become more rapid over the last years due to fast pace of new technological innovations. While services are changing more frequently, also underlying platforms need to be agile. These changes are not happening by themselves but by personnel of service providers, thus, knowledge must also be developed in the fast pace. To make this happen, an organization shall transform this into a strategic capability.

One approach to mitigate economical and technological challenges is to introduce a new platform, also known as the Telco Cloud. It offers service agnostic flexible capacity that builds a solid bedrock for different kind of network functions and services. Furthermore, the new platform enables new kind of business models. On the other hand, changing cost structures and likely strategic implications need to be understood properly so that exploitation of benefits of the new technology can be achieved.

This thesis is focusing on the use of cloud service model for producing telecommunications services. Motivation for this thesis is to understand better how a carrier can establish a strategic capability by building the cloud platform and how it affects the cost and service structures. To gain this understanding also the concept of the Telco Cloud is studied. Furthermore, this study contributes to Telco Cloud concept and cost structure model of it. Furthermore, this study contributes to the application on-boarding process model which can be deployed along the deployment of the Telco Cloud platform. The application on-boarding process can be used for managing the complexity of a service on-boarding to the platform.

1.1 Research Questions

The research design is carried out together with the case company. Three main research questions are identified during the research design phase.

Initial assumption for the first research question is that the Telco Cloud will change the cost structure of a network service production somehow. The objective is to find out the difference of cost structures between traditional platforms and the Telco Cloud.

> *How the Telco Cloud could change the cost structure of a network service production?*

Initial assumption for the second research question is that the Telco Cloud enables dynamic allocation and deallocation of a capacity. The objective is to find out how the cost structure is changed due to this nature and is there some kind of benefit realized.

> *Does dynamic allocation of resources bring any benefit for the cost structure?*

Traditionally network services have been implemented using special purpose service dedicated hardware devices. The initial assumption for the third research question is that the network function virtualization (NFV) paradigm is going to transform service models. The objective is to find service development model which enables efficient use of the Telco Cloud platform.

> *What kind of application on-boarding process can be used for introducing network service provider's services to the Telco Cloud platform?*

1.2 Research Objectives and Scope

Main objectives of this study are to understand how the Telco Cloud is changing a service provider's (i) economic operations, such as cost structure, processes, strategy planning and strategy implementation and (ii) technical operations, such as network function implementation, service development and implementation processes.

The single case study approach is selected as research methodology for this study. The case company chose to be anonymous, thus, the company is called *Company X* in this thesis. Company X had a project named *Telco Cloud*. The objective of the project was to build a platform for NFV purposes for telecommunications services. In this study the terms *Telco Cloud* and *Carrier Cloud* are used interchangeably. The research is carried out in collaboration with Aalto University and Company X.

First aspect of the research is the Telco Cloud as a concept and technological structure of it. Second, economic aspect includes the cost structure and comparison to traditional platform models. Third aspect is the strategic capability, which covers how the Telco Cloud is developed, how resources and competences are managed, and strategic implications of those. Part of this, the compliance analysis covers the legislative and regulatory aspect directly related to the telecommunications business from the economic and technology point of views. The legislative region is Finland.

The view point in this thesis is from service provider only. A customer view point is quite limited due to the length of the analysis. Certain limitations exist in the scope of this study to keep the length of the analysis reasonable. Limitations are discussed further in the conclusion, in Section 7.2.

1.3 Research Methods

To get proper view to the area of research questions, qualitative and explorative research is carried out. Theoretical data collection is done using a literature research. The empirical data is collected using semi-structured interviews in the case company. From these the results are qualitatively analyzed using the qualitative data analysis technique. The analysis is working as a base for the final contribution of this study.

Thus, this study aims to propose a framework for the Telco Cloud paradigm with cost structures and strategic implications. The overall research and model formation process can be seen in Figure 1.

1.4 Structure of the Thesis

The rest of this thesis is organized as follows. Section 2 reviews a literature of the Telco Cloud area. It also introduces relevant theoretical frameworks and methodologies. This background is used as a baseline for the rest of the research and it also forms the theoretical background for the research. Section 3 presents summary of the empirical study. Section 4 analyzes the research data. In section 5, suggestions are presented for a deployment of the Telco Cloud platform. Section 6 discusses more deeply the implications raised from the study. Section 7 concludes the study by summarizing the key findings and contributions, furthermore, suggesting a few opportunities for further research.

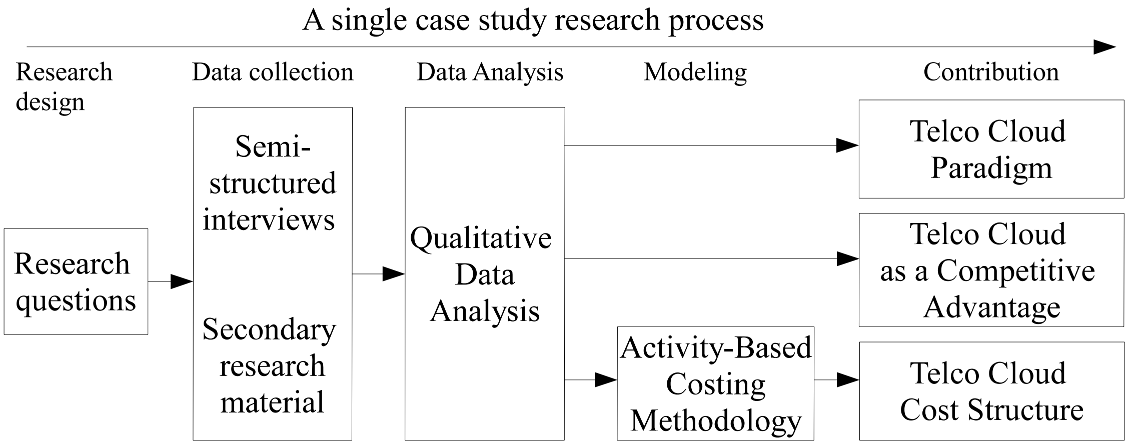

Figure 1: Research process of the Telco Cloud paradigm, cost structure and strategic implications

Seven appendices supplement the thesis. Appendix A lists all relevant telecommunications regulations. Appendix B presents background information of all interviewed persons to give some demographical information. Appendix C demonstrate the question template that was used in the semi-structured interviews during the data collection phase. Appendix D shows the NIST definition of the cloud computing paradigm that was used as a reference for that concept. Appendix E exhibits initial values and equations for cost level calculations. Those are used for simulating the cost behaviour. Appendix F reveals the concept network that is formulated during the qualitative data analysis phase. Finally appendix G lists all translated transcripts from the interviews.

2 Background

This section introduces the relevant themes and theories that are used in this thesis. Section begins with the literature review, including a short introduction to cloud paradigms. Followed by a short introduction to relevant business models. Second, theories of cost structures, cost accounting and market regulation are discussed. To fulfil a market and economic sides, strategic capability and software development areas are also covered briefly. Finally relevant research methodologies are explained.

2.1 Cloud Paradigms

The term cloud computing was coined in 2006 by Schmidt [8]. After that, several alternative definitions have been made to form the paradigm. The cloud computing concept precedes the Telco Cloud. However, the cloud computing paradigm has not yet fully reached the dominant design phase as several competitive models are available [9].

One of the most widely used definition for the cloud computing paradigm is the definition released by the NIST organization [10]. The definition covers three different perspectives. First, characteristics such as independence of usage location, dexterous and usability on demand. Compared to traditional information technology (IT) platforms, these features are quite different. Location independent computing requires a network platform that can connect users from a remote to central locations. Dexterous or convenient, indicates flexibility and easy to learn and to use. On demand features bring requirement to get a capacity when needed so that charging is also based on the actual use of resources. Second, the actual computing capacity is consisting of core resources such as networks, servers, storage, application and services. There might be also other value added services available. Third, provided resources can be provisioned and decommissioned fast so that manual activities and operational resources are kept in minimum. The full NIST definition can be seen in appendix D.

The cloud computing model has spread to nearly all areas of the IT industry. However, this haven't happened uniformly. Different users and applications have different requirements for the reliability and service levels. Thus, there have to be different kind of clouds available. One way to categorize different cloud types is to group those by the service level. Those clouds that are targeted to the consumer segment and the service is cheap or free have the lowest expected service level. On the other hand, the highest required service level is on company internal private clouds that are serving most business critical services of a company. [11] Figure 2 illustrates the division between different cloud types.

According to Dukaric and Juric [12], to achieve characteristics mandated by the cloud computing, many technological features must exist. The most critical factor is a high level of virtualization. This includes service virtualization in the form of network function virtualization (NFV). The server virtualization is not actually a new concept. IBM company has used the virtualization in its mainframe products since 1960s. The objective of the virtualization is to decouple the software, thus, the

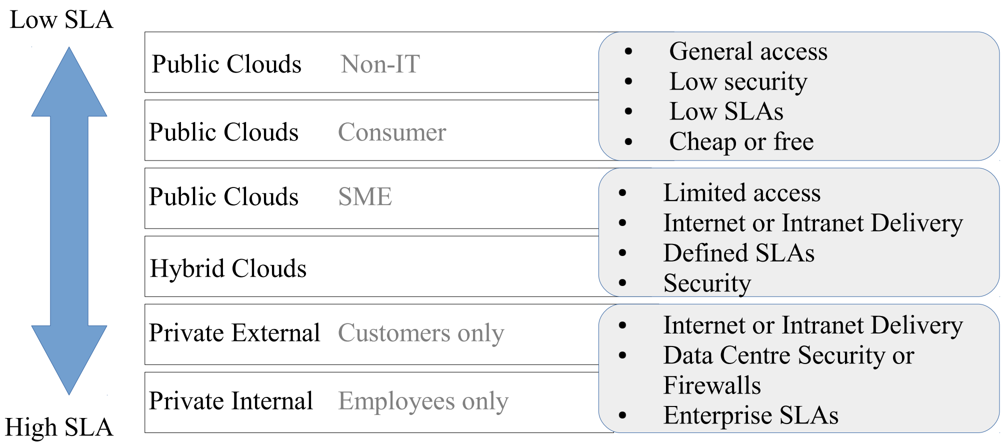

Figure 2: Different cloud categories have the distinctive types and quality levels of service [11]

application from a hardware. This enables statistical multiplexing and mobility of different workloads, hence, it improves utilization of a hardware. Furthermore, they propose a virtual infrastructure manager component which orchestrated physical and virtual resources so that individual components can be hidden from a user, thus, a user sees just a pool of resources.

2.2 Related Work

To get an overview of what the concept Telco Cloud means, a short literature survey is carried out. The survey reveals that Carrier Cloud and Telco Cloud concepts are very recent. The oldest mentioning of the concept Telco Cloud is from the year 2011.

In the literature review, different definitions of a Carrier Cloud and a Telco Cloud concepts are collected and compared. It can be seen that the Carrier Cloud and Telco Cloud paradigms are more or less the same [13] [14] [15] [16]. There is more variance between individual models than between these two concepts. The reason for the variance can be explained mostly by the different view-points. Two major schools of thought exist - mobile networking folk and fixed networking folk. The mobile oriented proposals have taken the virtualization of mobile network components such as an evolved packet core (EPC), a mobility-management-entity (MME) and even a virtualized radio-access-network (RAN) as a starting point [15]. The fixed network oriented proposals are mostly concentrating on virtualizing controller and application layers of the software-defined networking (SDN) infrastructure [17]. These do not exclude each other but are actually supplementary.

Bosch et al. [16] proposes the Virtual Telco concept which could be implemented on top of the Telco Cloud platform. Their paper is one of the earliest to introduce the Telco Cloud concept. In their model, the Telco Cloud is adapted from the cloud computing paradigm by adding the appropriate resource management layer.

They observed that only some of applications are compliant with the Telco Cloud platform. If an application does not meet distribution requirements it should be left out from the Telco Cloud. These excluded applications are called legacy software.

According to Taleb [15], the Telco Cloud architecture can be divided into five individual layers. The illustrative model can be seen in figure 3. Each of these layers have several sub components that might have different stakeholders. These stakeholders are responsible of running the operations of that individual component.

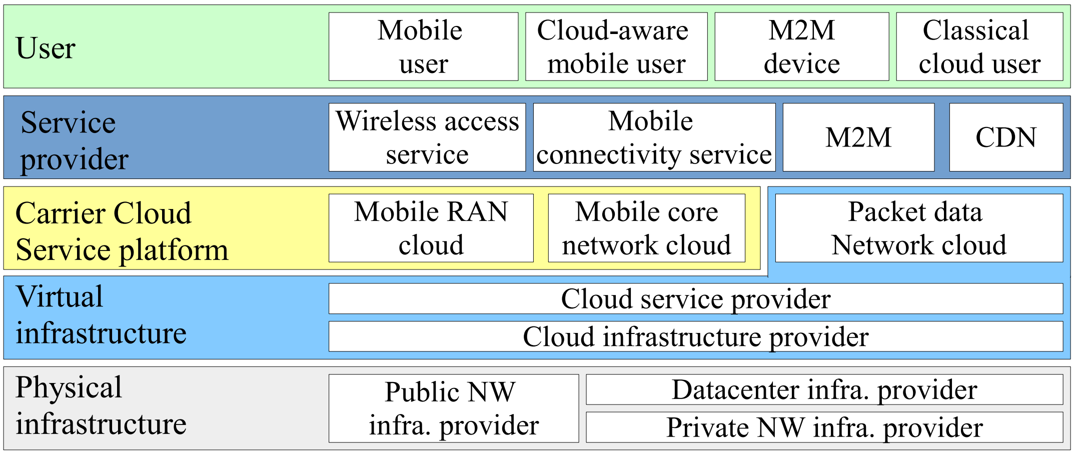

Figure 3: The Telco Cloud architecture can be divided into five layers and all those might have different responsible party [15]

- The physical infrastructure layer contains public network infrastructure that is a link from a data centre to the public internet. Actual physical facilities contain racks, a cooling, an electricity distribution and a security functions. A data centre also contains a private network infrastructure for interconnecting servers in a rack to each other.

- On top of the physical layer is a virtual infrastructure layer that contains two functions. The cloud infrastructure component is the first level of virtualization that is hiding any physical component from the application layer so that applications are seeing resources as pools of capacity. The cloud service component brings cloud intelligence by enabling inter-site load-sharing, redundancy and application awareness. The packet data network cloud component can contain practically any relevant cloud capable application that is serving upper layer applications.

- The carrier cloud service platform provides virtualized network functions (VNF) for upper layer applications, such as virtualized RAN.

- The service provider layer contains services that are visible to users. There might be very different services running on top of the platform. The mobility, content-delivery network (CDN) and machine-to-machine (M2M) services are just a few examples mentioned.

- The user layer represents all those different use case scenarios how the actual service is consumed. The user does not have to be a person but can be actually any thing, as in the internet of things (IoT) concept.

On the other hand, Krzywda et al. [13] present a design for cloud facilities. They propose two different type of data centres (DC). Remote DC is a large facility and is located relatively far away from access networks, optimally from the core networks point of view. Proximal DCs are smaller regional facilities that are close to access networks, thus, to users. Furthermore, access networks and the cloud infrastructure is quite closely integrated compared to the traditional model. The majority of a capacity is located in proximal DCs, thus remote DCs are for coordination and distribution controlling purposes.

According to Anderson and Tushman [18], on general level most of products and technologies are following their distinctive life-cycle model from a technological discontinuity to the dominant design phase. A characteristic of the era of ferment phase is that several alternative flavours and contradicting concepts exist before the concept settles and the dominant design emerges.

Hence, it can be said that the Telco Cloud paradigm is now in the era of ferment and it takes some time before the dominant design emerges. Although the number of published papers is relatively low, papers exist that propose some characteristics for the Telco Cloud or Carrier Cloud model. Some of the papers are reviewed next.

Yazıcı, Kozat, and Oguz Sunay [19] discuss in their article about the future directions of mobile control plane architectures. They envisage that the whole control plane will be running on fully virtualized, flexible and scalable environment that is called a Telco Cloud. This is supposed to yield a full programmability of mobile service provider's networks, hence, enabling new innovations of control plane functions. The paper does not take a position what kind of the platform would be.

Soares et al. [20] present the Cloud4NFV platform model. The model is solely intended for virtualized network functions (VNF), although they indicate that the same platform can be used for other purposes also. The platform model is based on major NFV standards and on de-facto applications such as OpenStack [21] and OpenDayLight [22]. The European Telecommunications Standards Institute (ETSI) reference NFV model [23] is used in their model. The study handles questions such as what and how to virtualize network functions. In their paper, the description of the Telco Cloud paradigm contains characteristics such as; automated deployment; configuration and life cycle management of services; service deployment and provisioning; management and optimization of cloud resources. The hardware specification is not accurate but contains components such as a compute instance, a compute flavour, a block storage and networks. The orchestration layers contain the cloud management function for intra-site controlling and the WAN management function for inter-site controlling. They state that, when the network is using cloud features to consolidate functions to a common hardware, a reduction in costs and faster time-to-market are achieved. However, the requirement is that reliability and performance must be on the carrier-grade level. Furthermore, they see that a generic hardware and cloud software enable open platform for innovation.

Soares et al. [24] present how network service functions can be brought into a Telco Cloud environment. The proof-of-concept model is built on top of the Cloud4NFV platform. The paper states that the traditional model of building network functions are based on overprovisioning to ensure appropriate service levels on estimated peak traffic and on the accepted risk of redundancy model where one single component can tear down the service. While the virtualization technologies have matured to a certain point, the carrier-grade capability to sustain reliability and performance expectations have also reached the feasibility. Hence, the expected consolidation is going to enable significant cost savings.

Hindia et al. [25] present the results of the cloud computing applications and platforms survey. In their multi-case study, a voice over LTE (VoLTE) service is the sample from the telecommunications industry. They used the EU FP7 Mobile Cloud Networking project's [26] definition as the reference. They found out that the OpenStack is one of those mainstream software that are lacking features to support the required functionality. Nevertheless, the required level can be achieved by extending features. However, parties that are implementing LTE services to cloud platforms should be aware of these issues. Hindia et al. [25] state that they see a great potential on the Telco Cloud model. Their position is that the Telco Cloud is going to enable new products and services to the telecommunications industry.

Zhiqun et al. [14] discuss the emergence of the Telco Cloud paradigm. They observed that operators can achieve reduction in costs by introducing cloud computing platforms. Their position actually is that deployment of the Telco Cloud platform is a necessity to ensure profitability in the long run. The cloud computing model greatly improves average utilization of telecom equipment due to virtualization. They state that the reduction in OPEX is mainly achieved by integrating an automation and orchestration to the service management process, thus, reducing manual activities. They also had a vision that the Telco Cloud will enable a virtual telecom operator concept through the open platform.

Krzywda et al. [13] propose a meta-model for the Telco Cloud framework. The model can be used for simulating different configurations, thus, observing behaviour of a system from performance and cost perspectives. They found out that a large scale testing environment for simulation of a whole Telco Cloud environment would be economically very expensive. On the other hand, a small scale simulation system is not able to observe all possible patterns in a user behaviour. In a scenario based approach most relevant attributes for the context are observed and simulated on whole system level. This way the simulation can bring adequate accuracy. Krzywda et al. [13] also present a model for the Telco Cloud system dynamics. The illustrative model can be seen in figure 4. The model has three stocks. The workload is an input to the system. It includes amount of requests to be served, amount of resources used by a service and statefulness of an application. Objectives are representing the output of the system. Quality of the service target and cost target are used as an examples. Setup is mostly defined in design phase in form of topology, capacity and DC locations, but also operational actions are having an effect how the system is performing. All these three functions are dependent on each other. The setup is mostly defined by existing workload in form of capacity requirement. Workload is also influencing objectives such as costs. Finally can be said that objectives are heavily dependent on the setup. [13] This system model can be seen also as a model for resource supply and demand process that is quite intrinsically intertwining to cost accounting and allocation [27].

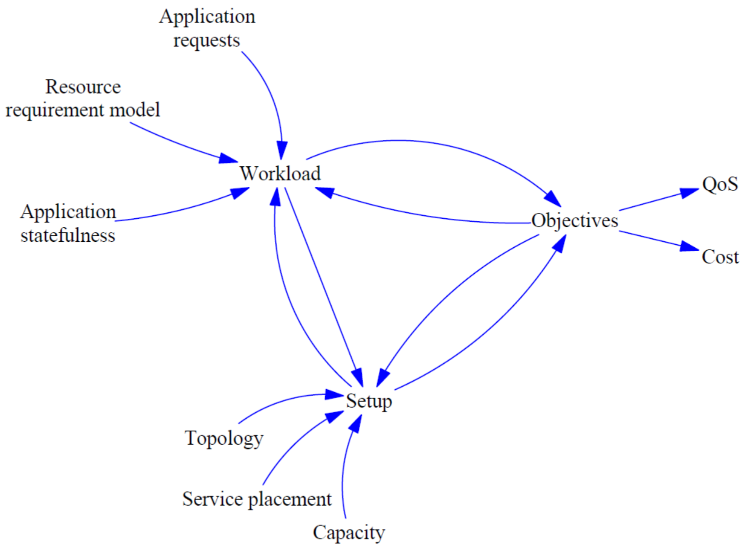

Figure 4: System dynamics model of the Telco Cloud (adapted from [13])

The literature study reveals that none of the reviewed papers is handling application on-boarding or strategic implications of the Telco Cloud paradigm issues. Furthermore, only one paper exists by Krzywda et al. [13], which handles cost structures of the Telco Cloud platform. However, this paper has modelling and simulation point of view to the context. Hence, the literature study reveals that an opportunity exists to use exploratory research on these topics.

2.3 Business Environment

The telecommunications service market has evolved gradually over the past two centuries. However, the telecommunications market has changed quite radically in the past 50 years due to increasing pace of new technologies and liberalization of legislations. Government owned telecommunications units are dismantled and privatized. Transition from an analog to digital technologies and the birth of mobile communication revolutionized communication services and opened totally new opportunities later in the 20th century [28]. Within the last decade, cloud business models have crowded into nearly all areas of the information and communication technology (ICT) industry. The Internet and cloud business models are gradually merging with the telecommunications. Yet again, the telecommunications market is at the dawn of a revolution.

In general, the term business model defines two essential items for a product or service. First, it describes the design of how a product or service creates a value for customers. Second, it defines how the provider can get a share of that added value.

[29] On the other hand, traditionally, a market has been seen as a layered chain of activities between stakeholders that produce value for a customer in a series - i.e. in value chains. The complex nature of the modern markets cannot be modeled using chains anymore. Recently the view has been extended so that the market is now seen as an ecosystem. These ecosystems can be modeled using value-networks. [30]

2.3.1 Telecommunications Service Market

The telecommunications market has several stakeholders that act in co-operation or in competition position. For example governance bodies, network equipment providers, content providers, service providers, system integrators, network operators, consulting companies, terminal suppliers, consumers, customers and end-users. [30] Emergence of mobile application ecosystems have blurred the line between traditional telecommunications and internet markets. Also the concept of a customer is changing due to multi-sided markets [31].

The traditional telecommunications market contains telephone services such as voice calls, mobile voice, short messaging and multimedia services. The specifications for these services are mainly created by ITU-T [32]. These services are typically charged using a call duration or event based approach, thus, usage-based charging is used. Many operators have implemented both pre- and post-paid subscription models. [33]

Another important service area is data subscription services, which contains two categories, fixed data and mobile data. These services are using variety of technologies and service offerings are quite diverse. Nevertheless, almost all subscriptions are currently flat-rate in Finland. Reasons for this are discussed further in the regulation part in section 2.3.3. Compared to other countries, the market in Finland is quite abnormal. Most operators in other countries are using block based pricing in the cellular data, in which users are paying incrementally for all the data they are transferring. [34]

The usage-based and flat-rate based services form telecommunications operator's core business in many cases [35, 36]. However, these service areas are heavily commoditized, the market has high competition and those product areas are regulated. These factors are forcing operators to seek also other revenue streams.

Those telecommunications services that are not core business are considered as a VAS. For example a hand-set bundling and OTT content are typical supplement services that many operator provides. Furthermore, different services can be grouped or bundled together so that the value for a customer is bigger than separated parts. Business models for these offerings can be very diverse. Currently, there actually is a starting trend that telecommunications providers are starting to offer VAS services for any customer, not just for those that have a subscription in operator's network [35, 36].

It has been argued that telecommunications core services have the most simplest business models. Typical customer segments in these services are the consumer, business and wholesale. The latter is the market between operators. More complex business models are those that are building on multi-sided markets or does leverage some platform capability. These business models contain more risks, but on the other hand also more opportunities. [37]

Service providers are suffering from continuously decreasing average revenue per unit (ARPU) values, declining service prices and increasing pace of emerging new technologies. Although local market differences exist, statistics indicate that this is actually a global phenomena which is transforming business models of every telecommunications operators. This has happened at least in Finland [6] and in the US [38].

Decrease of the ARPU in the telecommunications market has continued in Finland in early 2010s. As can be seen from figure 5-a, decline of the ARPU is happening in the fixed data and in the mobile services. However, the fixed telephone ARPU is actually increasing. [6] At the same time, most of the fixed telephony customers have migrated to the mobile services and just a few customer segments exist that are still using a fixed telephone networks actively [39]. The number of fixed telephone users decreased by 50 percent between 2008 and 2013 [7, p. 8]. This indicates that the increase of fixed telephone ARPU is not due to increased service quality but operators' opportunity to charge more those that are still seeing a value in fixed telephone services.

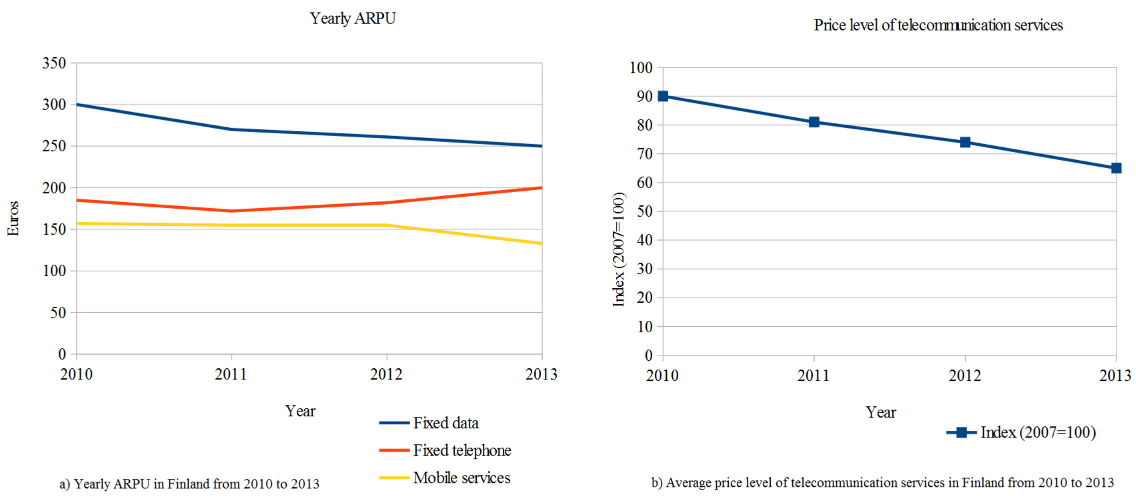

Figure 5: Development of the average revenue per unit and the average price level of services in Finland from 2010 to 2013 [6]

On the other hand, the average price level of a telecommunications service has actually decreased quite radically. The decline was 28 percent from 2010 to 2013. At the same time the ARPU declined only 9 percent. [40] The difference can be explained by the growth in use of services. Especially the use of mobile data was in boom [41]. Users are taking several subscriptions for different end-devices. Development of average telecommunications service price level in Finland from 2010 to 2013 can be seen in figure 5-b.

More and more traditional telecommunications service providers are entering into IT business areas. One option is to start a cloud computing or a cloud software business.

2.3.2 Cloud and Software Businesses

According to Qian et al. [8], several software companies exist that are providing either software products or software services for their customers. There have been efforts to enable from a product to service transition and from a service to product transitions within a company [42]. On the other hand, many providers have offered a computer capacity and software products as a service. It took quite some time before new paradigm took off in form of a cloud service. [8] In this context the term cloud software is interpreted such that it covers a software which is provided from a cloud computing platform with similar characteristics than the cloud computing.

A public cloud computing service contain five major characteristics. (i) A user can provision the required service by herself with minimal interaction; (ii) the resource can be easily scaled up or down; (iii) resources are measured; (iv) resources are controlled; and (v) the service is charged in a pay-per-use basis, such as hour based billing. [8]

Nambisan [43] compared the service and product businesses. He identified five key issues which differentiated those two areas. In here, all those are gone through and some new insight is brought in the form of cloud software business.

Intellectual property rights (IPR) are identified to be important for software product providers, but not for service providers [43]. The cloud software is positioning between these two areas but is more biased toward the product business area. However, the Web 2.0 [44] era has set the development pace to the high level which is making more challenging to retain a high appropriability regime and use protection mechanisms such as patents. The provider should protect its rights by using appropriate terms and condition clauses in customer contracts. However, when the software components are spreading possibly to several clouds and geographical areas, boundaries between IPR ownerships might get blurry. Software development companies should have strict contractual base, which also covers IPR issues, for all interfacing parties.

Product complementaries are important for product business because none of the product can function in a vacuum but must take into account surrounding systems and be able to integrate with those, while for service business product complementaries are not so important [43]. Yet again, cloud service is positioned between product and service business. Modern cloud software must be able to integrate with other systems to be competitive on the long-run. There certainly are some niche areas where integration is not crucial, but those are getting rare.

Product development costs are considered as a fixed costs while service business costs are mostly variable. To acquire high return from scale, product standardization and generalization must occur and reusing previous development should be applied. [43] The cloud paradigm is following exactly the product development model. However, it also enables an ecosystem in which third parties can exploit consultancy opportunities.

Successful product business requires abstracting the product knowledge so that same product can fulfil variety needs of different customers. Furthermore, by integrating core technologies into a software, a product company can leverage it's competencies. In service business the knowledge of every customers individual challenges is much more important than generalization. [43] In the cloud software the product oriented generalization and technology integration applies.

While a product provider has long-term relationship with customers, a service provider delivers services with short-term, project oriented, manner [43]. However, this can be argued that many service companies are certainly prolonging their customer relationships with sequence of projects and building deeper understanding of each customers problems. According to Qian et al. [8], the cloud business model makes a difference here. Highly possible is that no human-to-human customer relationship exists at all in the cloud software business. A customer can acquire the service from a self-service portal, create integrations with using pre-defined application programming interfaces (APIs) and optimize usage when needed.

The cloud software business model has many similarities with the product business model, build-once-delivery-to-many model. However, the cloud software model very cleverly leverage platform thinking where a customer can build and integrate different clouds, thus one can build a cloud of clouds. This kind of approach is not trivial and requires expertise of the area. Hence, the cloud software business model certainly enables many service business opportunities and creates an ecosystem. This software area and the Telco Cloud paradigms are brought together in Section 6.

2.3.3 Telecommunications Regulation

Many kind of regulations apply for telecommunications service providers. Regulation can direct domains such as pricing, services, financial reporting or how production is operationally handled. In this section is taken a look how those are seen from the telecommunications company point of view.

The European telecommunications market contains several levels of regulation. Figure 6 illustrates basic levels seen from Finland's market point of view. As Finland is the European Union (EU) member, all directives and regulations set by EU have to be implemented to the Finnish legislation. The Finnish government set laws for any activity happening inside Finland. [2]

Three categories exist in national-level regulation that regulated companies have to comply. Legislation sets the base for any legal activity, thus, any party operating on the market has to be aware of any legislative matter. Failing to comply with legislative matters lead to punishment of criminal justice. Another side is regulator driven directives. These regulations are building on legislation but are mostly done in the cooperation with ecosystem players. Failing to comply with these regulating matters may lead to withdrawal of business operations license or permission. The least enforcing regulation is recommendations which are guidelines and are working as a national level best practices for the local market. [2]

Regulators have many tasks in the telecommunications ecosystem. One of the most important job is to supervise and direct the market so that it functions efficiently. Feedback from ecosystem stakeholders is important for regulators to make wise decisions. Several ways exist to direct the market. Open cooperation with

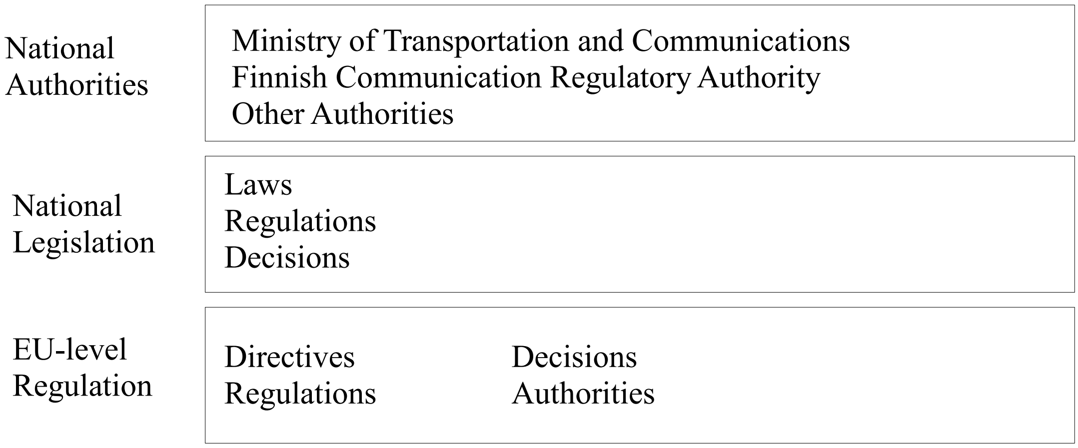

Figure 6: Levels of telecommunications regulation in Finland [2]

stakeholders is the best for nurturing healthy market development. However, when consensus cannot be reached, more powerful methods have to be used. [33]

If stakeholders are not complying with recommendations, a regulator has the option to transfer the recommendation status to the directive status. Intention of a regulator is to enforce efficiency to the market. According to Courcoubetis and Weber [33], the efficient market has three characteristics. First, allocatively efficient market produces goods that customers want and are willing to buy. Second, productively efficient market produces goods in an optimal manner so that opportunity costs are kept on minimal level. Third, distributively efficient market is produces goods for those that are valuing goods the most. Hence, if regulator finds that the market does not meet some of these characteristics, it can adjust a regulation so that the market situation changes.

The telecommunications regulator has had traditionally a strong role in Finland [2]. The legislation, both the EU and Finnish level, drives the higher level rule making policy. Finnish Communications Regulatory Authority (FICORA) is acting as a telecommunications regulator in Finland. Service providers are following quite obediently FICORA's recommendations. The possibility that FICORA will pass the recommendation to the legislative handling is a strong deterrence. If this was happened it would result more strict legal bindings, which is not beneficial for the market on overall level.

One example of regulator's intervene is the mobile regulation change in later 2000s. Until 2006, the handset bundling with a subscription was denied by the legislation in Finland. Within very short time Finnish regulator drove through portability of mobile numbers and legislation change to allow 3G handset bundling to activate the competition. This leaded to very aggressive price competition which lasted almost a decade. [45] During that time operator revenues were growing only due to even faster growth in the customer base. This kind of phenomena can be seen also on other markets.

By the 2015, FICORA has set many directives that are on the scope of this study [46]. All relevant directives that are considered related to the Telco Cloud concept are listen in Appendix A. The directives that steer functional requirements of a system are 8, 28, 33, 54 and 58. Rest of the directives, 53, 55, 56 and 69, are for non-functional requirements. Especially the regulation 55 is interesting in this context due to its cost-accounting orientation.

The directive 55 guides that an operator has to have a cost accounting system implemented for all operations regardless if the product is regulated or not. Direct costs have to be allocated directly to the product and indirect costs have to be allocated using a cause principle. The allocation results must be derived from a company's accounting records and the cost allocation system must support calculation of cumulative costs whenever price is set or updated for a regulated product. [47]

A common wisdom is that a market needs to be regulated only if not enough competition exists or if the market is functioning inefficiently. However, regulators can unintentionally make rivalry between competitors so severe that many smaller operators are played out of their business, hence, the market is concentrating to the hands of a few biggest player. A market with a few big competitors is called oligopoly [33, p. 154]. On the other hand, if the market is not regulated at the first place, market is driving toward oligopolistic situation anyhow due to network effects.

Traditional regulated network businesses leverage highly network effects. Oligopolistic operators gain major cost benefit due to larger customer bases. This same applies for cloud service providers. Deployment of a large scale data centre yields large CAPEX costs, thus, the level of fixed costs is high. Most of the current communications regulations are enforcing operators to build certain capabilities to comply with directives. It can be argued that the cost to fulfil regulations is not very heavily correlating with the extent of a customer base. Hence, economics of scale can be seen also in regulatory issues.

2.3.4 Financial Regulation

The International Accounting Standard (IAS) and International Financial Reporting Standards (IFRS) are meant as an internationally compatible financial reporting tool for public limited companies that are listed to a public stock exchange. The IFRS was taken as a mandatory in the EU countries in 2002. Over 100 countries were moved to the IFRS reporting by 2006. [48] Although the standard is enforcing primarily for public reporting, a company can use internally different reporting. This also has an effect how companies are running their internal financial reporting.

The IFRS standard applies only for public companies. Hence, no reason exists to apply the standard if a company has operations only in one country and is privately owned. Furthermore, the difference between the IFRS and the national accounting legislation in Finland is quite large [49].

The IAS 16 defines how assets are valued and how depreciations of those shall be carried out. An item is an asset if it is a property, plant or an equipment and it is producing economical benefit in the future and its cost can be measured reliably. Such an asset can be capitalized and depreciated in coming years. Hence, a cost of the capitalized asset will not realize at once, but during several years. This depreciation period can be defined asset by asset. [50] For example data centre facilities might have depreciation time of 50 years while a server might be depreciated in three or five years. According to this, also spare-parts for servers can be classified as an asset, but this is quite rare in reality. In practice, a lot of variation exists between companies.

However, for example software development costs can also be recognized as an asset if previously mentioned criteria matches. Therefore, the software is an intangible asset that contains an intellectual property right and a booking value for that. The financial reporting standard for an intangible assets are defined in the IAS38. [51]

2.4 Cost Structure and Cost Accounting Mechanisms

Every company that is developing services or products for their customers is facing challenges how different costs should be allocated to an end product so that it could be considered fair. A company that has only one or two products may find it easy to allocate costs but companies with tens or hundreds of different products may find this as an undoable task. This section is describing the basics of cost structuring, cost allocation and accounting methods.

Two major categories of costs exist that need to be allocated for the end product - direct and indirect costs [52, pp. 140-143]. (i) Direct costs are expenses that are fully related to the end product and those costs can be tracked from a source to the end product easily. For example in a wholesale market, expenses related to purchasing the source product can be fully allocated to the resale price. (ii) Indirect costs are those that cannot be directly allocated to a single product. Several sources or activities exist that are creating indirect costs. For example administrative costs of a factory cannot be directly allocated to different products but there has to be an allocation rule that is applied for the cost sharing. Quite evident is that the first one of these two categories is easier to handle. Thus the latter one is requiring more attention.

On the other hand, some costs are correlating with some external parameter. This external force is called a driver. For example there can be a correlation between costs and number of customers, traffic volume or geographical dispersion. The driver represents dynamic changes of a cost. If high correlation exists between a cost and the driver, the cost is called a variable. If no correlation exists, the cost is called fixed. It should be noted that in some rare cases the correlation can be even negative. [33, p. 179]

One more attribute could be added to the function, temporal dimension. A short-run incremental cost (SRIC) is an increase in costs when one unit is produced now. On the other hand, a long-run incremental cost (LRIC) is an increase in costs when one unit is produced in the future such that a company has had time to optimize the production. [33, p. 180] Especially in the platform business the LRIC is highly important characteristic because service providers can leverage this dynamic nature of a service production in their service pricing.

Corporate accounting standards make difference between expenses that are producing a value in the future and those that are not producing a value in the future. An expense that will yield a revenue in the future is called a capital expenditure (CAPEX). This kind of expense is capitalized into the company's accounting records as an asset with a long-term value. However, typical is that the value dilutes over time. Thus, the bookkeeping value is depreciated evenly over the depreciation period. Typically hardware purchases are accounted using a CAPEX. [50] On the other hand, a cost is called an operating expenditure (OPEX) if it produces all value for the company at once and it won't produce any revenue in the future. Typically expenses such as electricity costs and monthly recurring rents are accounted using an OPEX. Traditionally products and services that are consumed at once and that cannot be put into a stock are booked as an OPEX. [53]

Several alternative cost allocation methods are available in the literature. For practicality reason, two of those are covered here; the simple costing system and the Activity-based Costing (ABC) system.

The simple costing system is very elementary and coarse way of allocating expenses to end products [52]. Nowadays very few company find this method accurate enough for their operations but in this case it is a clear-cut to be used as an introduction to the context. Following is described how the system works. The overall structure of a cost assignment is shown in Figure 7.

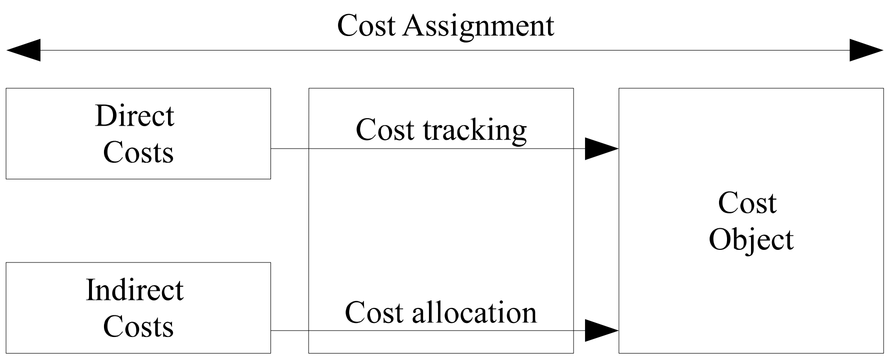

Figure 7: Simple Costing System [52, p. 100]

The cost structure in this system contains following elements. (i) Cost objects are desired targets for which costs are allocated. For example a product or a service. (ii) Direct costs are expenses that can be traced easily to the corresponding cost object. For example the SIM card of a mobile subscription. (iii) Indirect costs are expenses that cannot be traced directly to the cost object in an economically feasible way. For example maintenance costs of a mobile network.

Cost tracking and cost allocation are the two activities that are related to the cost assignment process. Cost tracking is the activity to search direct costs related to a cost object in question, using a reasonable effort. Cost allocation is the activity of distributing cost pools using simple cost-allocation base to different cost objects. [52, pp. 99-100] The cost allocation base can be for example relative share of the revenue between products.

The fully-distributed costing system (FDC) is a variant of the simple costing system. The model is a top-down model, meaning that the system leverage company's existing accounting records. The FDC had been widely used by telecommunications providers due to active promotion by regulators in the past. [33, pp. 163-165] However, due to extensive arguments against the model, regulators are abandoning it [54]. For example, in Finland, FICORA is currently giving freedom for regulated companies to choose accounting model that fit for their purpose best [47].

Braeutigam [54] argues that the FDC model does not reflect how the allocation will be done in the future, due to the fact that company's historic accounting data is used as a data source. Especially, the FDC model has no direct relationship to a marginal cost, thus, the model cannot guarantee that it would give economically efficient or fair allocation. The allocation rules are made using expert's estimation.

The ABC system is a refined method for structuring and allocating costs in a complex set up. While the simple costing system can be applied when the cost structure is straightforward, the ABC system is more flexible and scalable. [55] The model is based on activities. An activity is a task, phase in a process or an event. These are the activities that a company does. Overview of the ABC cost structure can be seen in Figure 8.

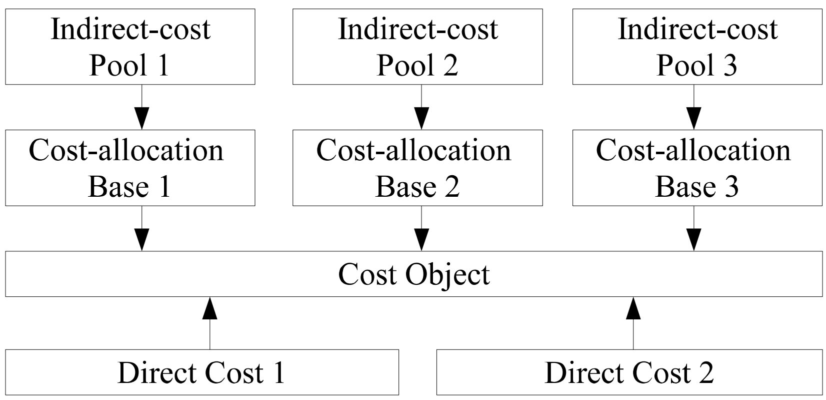

Figure 8: The activity-based costing system can model different kind of structures (adapted from [52, p. 173])

A cost structure in the ABC model contains (i) a cost object is the target for direct costs and allocated indirect costs related to the object ; (ii) direct costs are expenses that can be traced easily to the corresponding cost object - for example direct material costs ; (iii) indirect costs are expenses that cannot be traced directly to a cost object in an economically feasible way - for example platform development costs. The model is quite close to the simple costing system, but some major differences exist that makes the ABC model refined. Indirect costs are allocated to the cost pools so that each pool is representing one activity in a company. For each activity, a cost allocation base is defined. The cost allocation base is a calculatory quantity of produced units in an activity. The unit can be for example a piece, an hour or a subscription depending on the activity. Indirect cost pools are divided by the cost allocation base and assigned to the cost object. [52, p. 173]

Despite that the ABC method is also a top-down model, the model can be refined further by bringing a concept of network element between an activity and a service. A network element is representing a platform entity in the model. One network element can serve multiple services, thus, a need exists for allocation rule between a network element and services. By forming hierarchical structures also very complex environment can be modelled and managed. [33, pp. 184-186]

However, Courcoubetis and Weber [33] have a few arguments against the ABC model. First, the model hides any inefficiencies in service production due to a multilayer hierarchy. It does not necessarily give any motivations to enhance efficiency of a single underutilized network element. Second, all top-down accounting models are bad in estimating incremental cost of a service. Hence, to support different kind of scenarios, a company has to have a simulation based costing system so that also long-run incremental costs could be defined.

While the ABC model is not perfect solution for all possible cases, it is powerful tool to model static nature of cost structures in an established environment. In case of highly dynamic cost structure, it might benefit also to carry out system dynamic modelling to identify any dynamic behaviours of the system. The system dynamic can also reveal any implicit cause-effect relationships. For example regulators might direct how service redundancy must be applied when the customer base grows.

2.5 Software Engineering

Third industrial revolution [56] enabled especially ICT industry to emerge and to flourish. Almost all companies are nowadays using some kind of software in their operations to transfer manual processes into a digital world. Software is a base for many kind of solutions. A software engineering disciplines should be used to ensure a quality of software production.

Here are briefly covered a few most important areas. Requirement engineering (RE), Software quality and testing and Software evolution and life-cycle management processes are especially important when developing critical software components to a new environment while the expected life time of the platform is more than ten years.

2.5.1 Requirement Engineering

When a need exists to develop a new software or change old one, important is that user needs can be transformed to a measurable and implementable objectives. The goal of the RE process in software development is to do that. The RE can be applied using several methods. The basic principles are the same. [57, p. 83] The RE process take user needs as an input and from those ideas, which are sometimes very ambiguous, produce a software requirement specification, which describes unambiguously what developers should implement and what are the designed constraints. [57, pp. 91-92]

The very nature of the plan-driven software development method, thus also the waterfall model, is to plan and document very thoroughly all aspects of the software before proceeding to the next phase in the development project. This covers also the RE aspect. Hence, in waterfall model, the RE specification document is extensive and should describe all angles of the user needs in clear documented fashion. Several documenting methods are available, for example natural language specification, structured natural language and graphical notations. The RE process might sometimes take a lot of time before requirements are clear enough, thus possible is that this project phase run out of time and project proceed to the design phase too early. [57, p. 95] Though, analysis paralysis should be avoided and requirement planning should be kept on pragmatic level to ensure prompt progress.

Constantly changing business needs, which are common in the modern world, make sometimes the traditional plan-driver RE process quite useless due to the fact that user needs are probably going to change more rapidly than the process can deliver new releases of the software. That is what agile software methods was originally design for, therefore RE process must also support agile way of working. [58, p. 60]

According to Cao and Ramesh [58], several methods are available that enable RE specification formation in agile methods, such as face-to-face communication, iterative requirement engineering, extreme requirement prioritization, requirement change using constant planning, prototyping and test-driven development.

While the waterfall method emphasizes written documentation, agile method emphasizes face-to-face communication. Latter has an advantage if customer requirements are not yet fully matured or changes are expected. Some drawbacks can be identified. A customer has to be on-site with developers, which might be impossible on some cases. Furthermore, it might be challenging to make a conclusion when several interest-groups are involved. [58]

An iterative RE process enables incremental requirement specification in line with the actual development. For example in Scrum [57, pp. 72-74], the RE process is part of the sprint planning. This leads to high customer satisfaction and more unambiguous requirements. On the other hand, iterative process makes schedule and cost estimation more challenging than in waterfall model, and lack of documentation can cause communication interruptions in case of people change. [58]

Agile RE method prioritize high importance requirement in the process to maximize value for the customer on each iteration. This approach can enable value generation when customer can choose what benefit their needs the most. On the contrary, using strict customer based prioritization can lead to a poor architectural design, lack of security and instability due to crucial system functions might not be shown as important to the customer and, thus, prioritized to lower than other features. [58]

Though many differences exist between the RE in waterfall model and RE in agile model, the basic principle is the same. User needs must be converted to tangible requirement specifications. This enables, for example, testability of the features, what the software should and should not do. [57, pp. 83-113]

2.5.2 Software Quality and Testing

Several dimensions exist how quality of a software can be defined. According to Sommerville [57, p. 656], Boehm, et al. present that 15 major characteristics of software quality exist. Attributes such as safety, usability, testability, modularity and lack of complexity all increase quality of a software. On the other hand, Denning [59] defined that software quality is more on how well customer can be satisfied, promises fulfilled, no negative consequences produced and the customer is delighted.

An organization, which is developing a software system, must use appropriate methods to assure required level of a quality. The overall quality is combination of several factors - software testing, adequate processes, supportive culture and so forth. Software testing can be used for two major objectives. (i) To ensure that software meets its requirements, which were defined in requirement planning phase. Requirement document should clearly state how features should be tested to be considered compliant. (ii) Discovering non-compliant defects, which were born either in design phase or implementation phase. The purpose is to exhaust as many bugs, defects and flaws from the code as possible to make software stable, secure and reliable. [57, p. 206]

Several phases of the software production exist where testing can be applied. For example, during the development of a software product, (i) in unit testing, functions and methods are tested by calling those with different inputs, (ii) in component testing, interfaces between composite components are tested by purposefully calling components with correct and faulty inputs and (iii) in system testing the overall system is tested as a whole by checking that components are compatible with each other, especially separately purchased off-the-shelf modules with self-made code. Two first tests can be done by development team and the latter by separate dedicated testing team. [57, pp. 211-220]

Before the actual software product is put into production it can be tested by separate release acceptance team in form of release testing. When product is released, the actual end user can test the software and conduct user testing phase. [57, pp. 224-230]

Inspection is distinct from testing activity. Inspecting a software project is crucial to ensure that documentation is in place, discovered errors are handled appropriately by the process and check if project have followed the quality standard [57, p. 663]. At the same time, according to Porter and Johnson [60], software review is more effective when carried out individually non-meeting basely because individuals are able to identify more defects than what group can.

Quality management process is parallel for the software development process, although processes communicates with each other actively. The quality management process builds quality gates for each software project deliverables to ensure that output is compliant with organization goals and standards. [57, p. 653]

Practically is not possible to optimize a software system for all said 15 quality attributes. In project's planning phase, the quality plan must be made to select the most important attributes. The plan should be agreed with the customer as part of other non-functional requirements. [57, p. 656]

Currently quality management is heavily relying on software standards. While standards might introduce some overhead to the operations, it must also bring some value to the software in form of enhanced quality. [57, p. 659]

International Organization for Standardization (ISO) is one of the major stakeholders which are bringing common models to the industry. ISO 9000 quality standard track includes standard for software quality. The ISO 9126 was withdrawn in 2012 [61]and updated by ISO 25010 [62]. It was introduced to steer whole systems and software engineering quality requirements and evaluation. Furthermore, International Electrotechnical Comission (IEC) has defined standard for safety and security-critical systems, IEC 61508 [63].

Agile projects, which are not emphasizing documentation, are not commonly using standardization organization models, but instead developed their own method for handling quality management [57, p. 662].

IEEE has released wide used terminology for software engineering, with name 610.12 [64]. This document is now superseded and replaced by 24765-2010 [65]. Furthermore, ISO, IEC and IEEE have co-developed a series of software testing standards [66].

Agile methods are taking advantage of iterative model and flexibility. Review process is very streamlined. For example, in the pair programming, another person is continuously looking what is been developed and can identify errors more rapidly. [57, p. 665] The test-driven development model represents the extreme. In this model the actual test cases are created even before the actual functional code is been written [57, pp. 221-224].

The whole concept of quality is ambiguous. Instead of talking about overall quality, which is hardly measurable by one metric, whole concept should be divided to those 15 sub categories mentioned by Boehm, et al. Either case, to be able to achieve high quality software product, the organization as a whole should follow very carefully principles of software engineering.

2.5.3 Software Evolution and Configuration Management

Continuous integration model can be seen as an enabler for fast software delivery [67, p. 370]. The model is commonly applied with agile methods, especially with extreme programming. In continuous integration, frequent system builds are typically carried out daily or even after every code change, moreover to pinpoint possible problems an automated testing system is utilized. [57, p. 697]

The use of continuous integration model has advantages. First of all, it reduces risk. When several developers are contributing to the code of a software, possible integration problems can be identified and repaired quickly when the code is integrated to mainline frequently. This leads to less buggy code, so overall quality is improved. Furthermore, automatic testing saves a lot of developer time, thus reduces costs. Yet, the project does not contain huge integration phase because it is already done during the development. [68]

On the other hand, if a system is large and compilation time grows beyond practical limits, it might be impossible to compile the software after every code change. This does not prevent the use of continuous integration practices but it just slows it down. Furthermore, in a host-target development model, automatic testing requires existence of a target platform, which is not possible on all cases. [57, p. 698] One example to overcome this limitation is to use server virtualization as Stolberg [67] did when they started to implement continuous integration practices.

Continuous integration can ensure that each clean build is tested and ready for deployment. If some build or test fails, the log is delivered to developers for further analysis. After the bug is fixed, the build and test process starts over again. When implemented properly, the model reduces the need for separate acceptance testing and also release testing on some cases. [69, p. 15] While traditionally software evolution has been divided into development and maintenance phase, the continuous integration model enables merging of these two.

Chapin [70] argues that, when using agile method and especially continuous integration, only the initial specification phase and the very first iteration is actually software development and subsequent iterations are actually part of the maintenance phase. This sets the whole software evolution into a new perspective. There is no practical difference if continuous integration is used in early phase of the software lifetime or later when operations are more maintenance type activities. This approach helps to overcome many obstacles that in traditional development would be challenges, for example hand-over from development to maintenance.

To be able to utilize continuous integration efficiently, a single code repository must exist. The repository is also functioning as a configuration management system. The system contains information of what code version is included in the baseline. There may be multiple concurrent versions in use in different releases and also several platforms to support. [57, pp. 681-682] The continuous integration practices is building on top of well-defined configuration management tools, so that build system and testing automation can function without human intervention.

In addition to system building and version management, the configuration management concept also includes release and change managements. [57, p. 682] Continuous integration enables more rapid pace for implementing changes and testing automation ensures more cleaner code base for release management, so actual deployments can be done more frequently than without continuous integration.

For example, Stolberg [67] discussed about their experiences of deploying continuous integration practices and observed that when basic tools are missing, applying continuous integration practices are very challenging if not impossible. In implementation phase, an automation framework need to be created and processes need to be fine-tuned. After these changes, with cultural change, the continuous integration started to work and results were positive.

Continuous integration practice is very powerful method to speed up software maintenance and release cycle. Supporting systems must be implemented before model can be utilized and developers must be culturally on right track so that responsibilities are understood correctly. The one who makes a bug to the code and breaks the build should fix it as soon as possible, so that others does not have to wait.

Those service providers that survive the competition are not chosen randomly but by successful selection of strategic actions. However, it should be noted that same regulation applies to all service provider in a country, hence it is matter of internal strategic capabilities and how those are managed to be leveraged if a company success or not. Thus, the next topic is strategic management for a telecommunications operator.

2.6 Strategic Capability and Competitive Advantage

Strategic decisions have had a great effect to different events and their outcomes in the history. One of the known metaphors is the story of David and Goliath [71]. By choosing a right combination of effective actions, a party that is apparent looser can actually defeat the competitor. One can leverage its strengths and target those to the weaknesses of the competitor. However, to get an paramount view of current position, strengths, weaknesses, desired target objectives and possible required actions one has to carry out a strategic analysis, decision making and implement those decisions.

The field of strategic management is vast and ambiguous. As Mintzberg et al. [72] vividly described in their book Strategy Safari, the strategic management is at least ten different viewpoints in stead of just a one concept. In this section, relevant strategic management areas are described. The intention is not to introduce to all possible frameworks but just to those that are used for analysing situations in the research. Figure 9 illustrates the formation of competitive advantages that are building on clear chosen generic strategies and well managed strategic capabilities.

According to Johnson et al. [73, pp. 70-71], to form a strategic capability, two distinctive areas need to be present. First, the resource view covers what a company has and what assets it can leverage. Second, the competence view covers what a company does well, including knowledge and processes. For both of these areas physical, financial and human dimensions are present.

- On the resource side, physical resources are assets that a company can use for producing a value. Financial resources are company's abilities to sustain appropriate funding for the strategic capability. Human resources covers required people to build the capability. These are not just company's own personnel but also customers, partners and suppliers.

- On the competence side, physical competences are ways of doing actions efficiently such that flexibility and productivity is retained. Financial com-

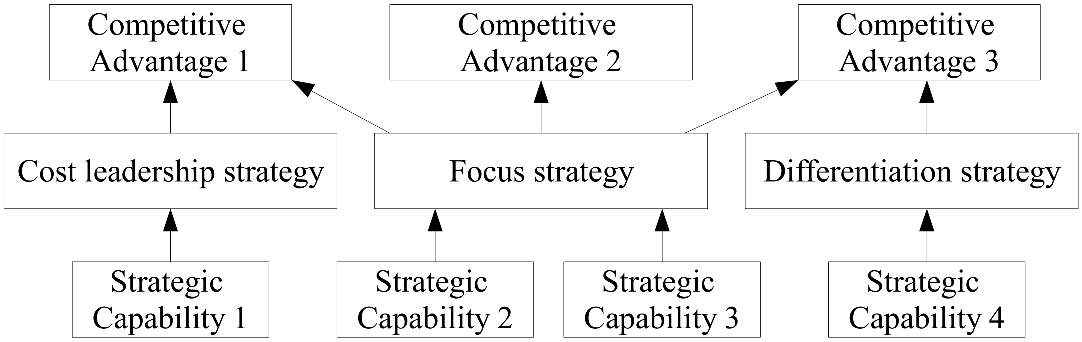

Figure 9: Formation process of a competitive advantage (adapted from [73, pp. 70-97])

petences are abilities to manage cash flow and if necessary also raise more funds. Human related competencies are personnel's knowledge, both explicit and tacit; ability to innovate; actions to gain and use experiences; and skills.

However, it can be argued that these two categories are not restricted to physical assets but also intangible assets can be counted in. For example patents, IPRs and licenses.

No strategic capability can remain static but those must be adjusted from time to time. A dynamic capability is a company's ability to change strategic competencies so that it would meet the needs of changing environment. According to Teece and Pisano [74], three areas exist that support emergence of a dynamic capability. (i) Integration. A company must be able to integrate different internal and external activities and technologies. This integration also includes way of coordinating and combining activities. (ii) Learning. Using experimenting and repeating a task many times, the task could be performed better and faster. Yet, a possibility exists to identify new production opportunities. Learning takes place on the level of an individual and on the level of an organization. (iii) Reconfiguration and transformation. A modern business environment is in constant change, hence a company needs an ability to observe needed changes and to adapt to those quickly. This skill is learned on organizational level. Furthermore, structures that emphasize local autonomy and decentralization help these processes.

A company must also have means to manage capabilities. Several actions exist that a company can consider. Internal capability development contains activities for building or combining capabilities. When creating a new capability, one must consider how the capability is promoted to the organization so that others will accept it. Furthermore, an existing capability might be underutilized and is has to be leveraged wider in the company. [73, pp. 94-97] However, it has been argued that transferring capabilities might actually be quite challenging, due to the same forces that allows different companies to differentiate from each other [75]. Moreover, one might observe that the capability could be stretched to other areas by extending or copying the capability. The capability can be also extended to external stakeholders, using for example alliances, partnering, acquisitions, joint ventures and innovation contents [76]. However, when external stakeholders are involved into strategic capability development, a company must be able to protect a valuable knowledge, IPR and other intangible assets [77]. A capability can be ceased if it was found to be outdated and it makes no sense to adjust it [73, pp. 94-97].

According to Porter [78], three generic strategies exist that a company can leverage in its operational domain. (i) The cost leadership is a strategy in which a company tries to reach a high efficiency and minimized costs. In this strategy, the company tries to acquire as big market share that is feasible and realize economics of scale. However, this strategy does not realize as is, but it requires at least one strategic capability underneath to be successful and sustainable. (ii) The differentiation is a strategy in which a company tries to build a unique product or product line which justifies to have higher prices than the industry average. The distinction can be for example a brand, feature or technology. The quality level must be set to high and customers are expected to get a lot of value from the product. (iii) The focus is a variation of the differentiation strategy. In this strategy the unique product is targeted to a specific customer group. By limiting the target segment, a company can optimize the delivery, marketing, production to extreme. Hence, in ideal case it can achieve combination of the differentiation and the cost leadership in the market.

The strategic capability, dynamic capability and generic strategies are building the foundation for competitive advantages. When these are utilized and a company can outperform competitors on the market or in the industry, the company has managed to reach a competitive advantage. [79] However, the situation is not lasting forever. Others are copying and imitating what they can and new technologies are emerging.

Companies are creating a value when they produce products or services for customers. The capacity of a company to take some part of this value for its own benefit is called appropriability. [80] On the other hand, a low appropriability regime indicates that innovations and knowledge are hard to protect in a market while a high appropriability regime indicates that those are easy to protect using patents, IPRs and trademarks [81].

It has been suggested that the innovation strategy would be the fourth generic strategy [82]. Others have seen that the innovation is a capability of a company that can be utilized as an internal and external activity [30]. No matter which point of view is chosen the innovation activity is one of the most important sources of renewal and growth for a company. This is also true in the context of the Telco Cloud capability.

2.7 Research Methodologies

In scientific research is crucial to choose right methods and theories. The task is even more important if the research has multidisciplinary objectives. The most relevant research methodologies related to this thesis are described in this section.

To understand the phenomena behind the research problems, the qualitative and explorative research is carried out. Theoretical data collection is done using a literature research. The empirical data collection is carried out using semi-structured interviews in the case company. From these results, analysis is carried out using the qualitative data analysis technique. The analysis was working as a base for the final contribution of this study.

In empirical research, the approach can be descriptive, predictive, explanatory or exploratory [83]. If the subject of the research is not well known or is quite recent and the theoretical base is not yet solid, an exploratory approach can be used. According to Hirsjärvi, Remes, and Sajavaara [84], exploratory method can be used for generating hypotheses, finding new perspectives, and for investigating new and poorly known phenomena. An exploratory research is common way to study a phenomena that is not in a scope of any existing theory. An exploratory research is typically qualitative and is carried out using a case study approach. In qualitative research a qualitative methods, such as interviews, can be used. However, Armstrong [85] argues that the use of an exploratory research method should be avoided. The argument behind his statement is that the research may produce non-true conclusions or useless theories without any theory behind it.

Another issue with an exploratory research is that generalizations need to be justified more thoroughly. A generalization is not usually simple and linear process. The generalized model must be a clear-cut in the context, it must be qualified and the relation to other generalizations should be unambiguous. This includes inductive reasoning, meaning that the collected data is analysed diversely and purpose is to find an unexpected but not actually test a theory of hypothesis. [86] Furthermore, the ability to generalize a single case study results is limited [87], thus too extensive postulations should not be made.

According to Kvale [88], an interview can be carried out using a structured, semi-structured or un-structured method. In structured interviews an interviewer uses a pre-defined question template and only those questions are handled. Queries are quite restrictive and part of the interview might contain closed questions that can be answered by a single word. In a semi-structured interview, an interviewer has the interview questions structure, but also any other issue can be discussed if the question is found to be relevant to the topic. Queries are typically open questions such that the question setting does not steer the answers to any direction and quite lenghty answer is expected. In un-structured interviews an interviewer indicates a topic for the discussion without any pre-defined questions and topics are discussed freely.

A scientific reasoning cannot be done purely based on an exploratory research, hence, a need exists for supportive secondary researches. According to Stebbins [86], one natural way to support exploratory research findings is to carry out an extensive literature research. The literature review should conclude so that there actually is no work done on the area. Or the previous work is very limited. The lack of the previous research justifies the use of exploratory methods.

According to Eisenhardt [87], a single case study research typically collects data from several sources, such as interviews, secondary sources or literature study. The method can be used if an understanding of dynamics of one single setting is needed. According to Hirsjärvi, Remes, and Sajavaara [84], when analysing the data, a judgement sampling is used for getting most relevant information out of interviews to understand new viewpoints instead of formulating statistical generalization.

According to Dey [89, p. 38], the qualitative data analysis method can be applied also for a small sample space researches as an analysis tool. The source data can be a snapshot of a situation, for example collected using interviews. In this case, the data is descriptive and reveals the qualitative details behind events and their relationships. The analysis process is typically started as soon as the data collection starts, not waiting the completion of it. This enables usage of an input from one interviewee to be used as a catalyst for further data collection. Important aspect is that field notes are taken and analysis is carried side by side the data collection. However, important is to separate the analysis results from researcher's own opinions. The qualitative data analysis process starts with labeling different events and objects observed during the data collection. Then labels that are like are grouped to form categories. These categories are split or spliced when needed. Interatively analysing each category, gradually the overall concept emerges and relations between categories and their sub categories can be revealed. When linking categories, important is to define the relation type between entities. This link might explain causal relation, cause and effect, between categories.

3 Interview Results

The design of the study and summary from the interviews are presented in this section. The actual data collection is carried out using an empirical and explorative approach, thus, the data is collected using semi-structured interviews. Furthermore, some secondary data is collected in form of Company X internal documentations. The intention is to find out new viewpoints instead of making any statistical analysis.

All interview notes are translated and transcribed after each session. The full interview transcripts can be seen in appendix G. Here are presented some of the most relevant observations that are made during the data collection. This section does not contain any analysis but this forms a summary of the interviews.

3.1 Case Selection and Introduction

The empirical and exploratory research is chosen to be carried out as a single company case study. Company X is a service provider that operates globally but the main operational area is in Finland. The company is providing mainly telecommunications, over-the-top, and enterprise IT services, including IaaS. However, the service portfolio contains also services like online gaming, digital information displays, digital payment and subscription based video services. Revenue of Company X was over 1,5 billion euros in the financial year 2014 and it had almost 4100 employees. Company X's customer segments are enterprises, consumers, public organizations and operators.

Company X is providing several cloud services for enterprises and consumers in IT and entertainment service segments. However, the cloud production model is not yet utilized in the telecommunications service production. Company X is considered as a good target for the research because they have a project ongoing which objective is to build and introduce the Telco Cloud platform for VNF services. Company X is also willing to support the study and allows data collection in the company.

The key objective of the study for Company X is to acquire knowledge of the Telco Cloud cost structure. During the initial interview with Company X representative, four main aspects relevant for the project were identified as key questions. (i) Telco Cloud's cost structure - how it differs from legacy platforms. (ii) Is there an opportunity to achieve cost savings by exploiting automation and standardization in the underlying platform. (iii) How processes, development models and employee knowledge must be developed to be able take advantage of the platform. (iv) VoLTE service roll-out is in the planning phase. How this service is fitting to the Telco Cloud platform. Furthermore, in particularly, the representative felt that the cost structure and the application on-boarding process need most attention.

3.2 Data Collection

Total of eight semi-structured interviews were carried out using face-to-face meetings or teleconferencing. The selection of the interviewees was made by the company representative. All interviewed persons are in some kind of managerial positions.

The criterias for selecting interviewees are their role in the Telco Cloud project, prior knowledge on the area and their formal position in the case company. Some of the persons are not part of the actual Telco Cloud project but are actually representing a user organization or support organization of the coming platform. All interviewed persons have a different view point to the context. One of the persons is representing the top management team and is able to give comments from that perspective. One is representing the sourcing and purchasing unit. Two of the persons are representing the software production unit. Background of one of the persons is in IP networking and he is contributing from that point of view. One of the person is acting as enterprise architect. He is in the charge of overall corporate level service architectures. Two of the persons are representing the data center production unit, the unit that will be in the charge of Telco Cloud operations and development after the deployment. List of the person level details can be seen in appendix B. However, all interviewee names are excluded for anonymity.

The interviews were carried out between May 29th and June 24th, in the year 2015. All interviewees were invited to the discussions by sending a brief introduction e-mail. Interview questions were not delivered to the interviewees before the meeting. Each person was interviewed individually by the researcher. Interviews lasted approximately one hour each and all answers were written down during the interview. The interviews were also recorded for annotation purposes.

A pre-defined question template was used as a baseline for the interviews. However, also some additional viewpoints were covered during the discussions. The question template can be found in appendix C. All interviews were carried out using Finnish language and all notes were also written in Finnish. However, all answers were translated to English right after the interviews so that the essence of the answers were not modified. Only relevant parts of the discussions were transcribed due to quite lengthy non-relevant parts of the discussions. Hence, the interviews were not transcribed totally. All references to individual companies or persons were removed from the transcripts. All recordings were deleted permanently right after the transcriptions due to confidentiality and privacy reasons.

3.3 Cloud Service and Telco Cloud Paradigms

In the first part, all interviewees were asked how they would define the terms Cloud Service and Telco Cloud. The intention with this question is to get an overview how people see the concepts and whole industry, yet how people see the paradigms and how they link those to the technology and business.

All interviewees have some opinion on what the cloud service is but some variation exists. Common view is that services are location independent, thus, a user can access a service via Internet. Some interviewees also emphasize geographical distribution of a service. Furthermore, a user does not need any own hardware, but shared capacity pool of a cloud provider can be used instead. Subscription and pricing models are seen flexible and the billing is usage-based. Many interviewees see that characteristics like automation, dynamic capacity, scalability and integratability between providers are also important.

Most of the interviewees have an opinion that the Telco Cloud is a platform that meets requirements of the telecommunications industry. This covers regulatory matters and network function virtualization. Furthermore, most of the interviewees stated that the Telco Cloud is using the cloud computing model underneath.

3.4 Structure of the Telco Cloud

In the second part, all interviewees were asked what kind of structural components they can identify from the Telco Cloud. The intention with this question is to get a detailed picture of from what kind of structural levels and operations the Telco Cloud is forming.

All interviewees said that the Telco Cloud is consisting of physical servers, virtualization, cloud layer and actual applications on top of the platform. Furthermore, several other components were mentioned, such as data centres, networks, orchestration and application life-cycle. Only one contradiction between respondents was identified. Some said that the storage in the Telco Cloud is a physical device while some said that storage is a virtualized component.

Most of the interviewees have an opinion that the virtualization layer hides the hardware layer, thus applications are seeing the platform as a resource pool. Furthermore, several opinions exist about the cloud layer. Instead of just one cloud or orchestration layer, the interviews indicates that several cloud layers and automation software have to be used for different part of the platform.

3.5 Financial Aspects of the Telco Cloud

Financial aspects of the Telco Cloud were discussed in the third part of the interview. This part covers what kind of capital and operating expenditures each previously mentioned component contains, what are those drivers behind each cost item that forces cost to increase or decrease and what work related activities are behind those. Furthermore, it was discussed which of the activities can be automated compared to a traditional production model and which of the activities have to be done by human.

Interviewees mentioned several tasks and activities during the interviews which are related to the platform. Activities, such as a hardware and software maintenance, an incident management, a platform maintenance and integration work, were activities that are necessary to keep the platform running. On the other hand, activities, such as a software development, personnel trainings, a capacity management, an installation, a vendor management, a new application on-boarding, a platform specification management and an internal communication are activities that are required to extend, optimize and develop the platform and its capabilities.

Interviewees also mentioned several cost sources related to the mentioned activities. Costs like hardware purchases, software license purchases and installations are considered as a CAPEX. Variety of maintenance costs and small development costs are considered as a OPEX cost. For example, an electricity cost, a hardware maintenance, personnel costs and repair costs are part of those.

Some of the interviewees mentioned that a driver is the concept of a force that is causing a cost to increase or decrease. Thus, a driver represents the causal relation between a driver and a cost target. Most of the attributes are technically oriented, such as an application complexity, requirements of an application and a geographical dispersion. However, some interviewees also mentioned business originating drivers, such as a growth of the user base and a competitive situation on the market.

Several interviewees have the opinion that the mass of applications is going to yield *economics of scale*, thus, reducing per application costs. Typical comment was that a virtualization improves investment efficiency, thus reduces CAPEX costs.

Most of the interviewees have an opinion that by keeping the amount of personnel related activities low some financial benefit can be achieved. This could be done by utilizing an automation so that a manual work can be removed in a service chain from end to end. However, all interviewees said that hardware installations cannot be automated.

Some of the interviewees indicated that the cost structure and an application cost should be clearly defined and communicated in a company. Especially if new services are prototyped and expected application life-time is short, necessary is to have clear knowledge of the cost level. However, none of the interviewees mentioned internal pricing.

Furthermore, some of the interviewees have an opinion that each new service which is on-boarded to the Telco Cloud platform must be compared to the corresponding traditional model to ensure the economic feasibility. It is seen that the target automation level of an application can be adjusted in the analysis phase to meet the target cost level.

In the case company, there have been two pilot telecommunications service applications that are prototyped in the cloud environment. Another one is the voice over LTE (VoLTE) service and another one is the domain name system (DNS) service. Two of the interviewees were part of these pilots respectively. Both of these interviewees stated that these pilot cases showed that cloud deployments are actually more expensive in a small scale environment than the traditional model.

3.6 Comparison of Traditional and Telco Cloud Models

In the fourth part, all interviewees were asked how a Telco Cloud platform makes difference compared to traditional telecommunications service platforms. The intention with this question is to get a detailed picture of how the cost structure of a service is changed when the service is transferred from a traditional service platforms to the Telco Cloud platform.

Most of the interviewees have an opinion that automation is one of the biggest functional difference between models. By utilizing automation, several manual activities can be reduced. On the other hand, many said that added software layers, such as the cloud software, are going to add new components and costs.

Several interviewees mentioned that a cloud model platform requires different kind of knowledges. Skills like application on-boarding, cost analysis, application life-cycle management and capacity management.

Interviewee, who worked in one of the pilot projects, stated that a major difference is how redundancy is implemented in a service level and how it affects to the economic side. In traditional models, several clustered servers are side by side. In the cloud model the redundancy should be on the application level. This is seen to open an opportunity to decrease hardware maintenance service levels. Thus, hardware maintenance costs and over-time expenses can be reduced by moving majority of incident repairing activities to the office hours.

Several interviewees said that by utilizing virtualization and consolidating hardware, the overall utilization of the hardware can be improved. At the same time, a floor-space in the data centres can be saved by removing application dedicated racks.

Many interviewees have an opinion that the vendor management is going to change while moving from a traditional to the cloud platform model. Previously platforms have been delivered as turnkey solutions. In the cloud model, a company has to do an integration work by itself and combine software from several sources. However, one of the interviewees observes that the industry is not necessary ready for the cloud technology yet, due to lack of a standardization.

3.7 External Forces

The role of Finnish regulator and Finnish legislation in the domain of the Telco Cloud was discussed in the fifth part. Furthermore, responsibility issues between several stakeholders were discussed. The intention with these questions are to get an overview of what kind of external treats and opportunities exist which must be taken into account.

All interviewees who were able to answer to the topic have the opinion that FICORA is not going to introduce any new regulation due to the Telco Cloud platform. Many saw that the new platform is actually easing to comply directives. For example, one of the interviewee said that in the 5G mobile network services are closer to customers in mobile sites, thus a fault domain is much smaller due to geographical distribution, yet this improves an overall service usability.

Some of the interviewee have an opinion that regulatory directives have to change due to changing technical solutions. Previously directives have defined a redundancy on the level of a device. In the cloud model, the redundancy is moved to the application level and one single device is not redundant at all. One of the interviewee continues that operators should open a discussion with the regulator to adjust directives.

Contractual responsibilities are also discussed during the interviews. Some of the interviewees have observed that in the cloud model a company has to take bigger responsibility. In purchasing contracts, a liability have traditionally been bound to a revenue to the vendor. In the cloud model, there will be many smaller vendors, thus liability is spreading to several smaller pieces.

3.8 Business Perspective

In the sixth part, it was discussed which are those critical factors that must be in a such condition that business can rely on the Telco Cloud platform. Services such as SMS and VoLTE/IMS are considered as a reference services. The intention with this question is to get an overall list of the items that should be checked when the service is transferred to production in the Telco Cloud.

All interviewees have different view point to the topic. However, two of the interviewees commented that a platform monitoring, automation and testing systems must be functioning flawlessly to ensure that promised service levels can be achieved. Furthermore, one of the interviewee have observed that cooperation between organizations should be on high priority to ensure that the internal and external communication functions appropriately.

3.9 Knowledge, Processes and Strategy

In the seventh and the last part were discussed what kind of knowledge development and application on-boarding processes must exist when transforming to the Telco Cloud model. A strategy related issues were also discussed briefly. The intention with these questions are to get an overview of what kind of new knowledge, organization roles, intra- and inter-organizational collaboration bodies and strategic planning and implementation tools are required to support a development and operations of the Telco Cloud platform.

Several interviewees have an opinion that several technological knowledge areas exist that are emerging with the Telco Cloud model. OpenStack is raised as one of the most important technologies that requires strong knowledge in organizations that are developing and operating the Telco Cloud platforms. Another mentioned technological area is Linux systems - especially so that networking and server system specialists should exchange knowledges and do things more together. Some of the interviewees also mentioned that a need exists for knowledge that is crossing technological boundaries.

Some of the interviewees mentioned that understanding of software based solutions must be improved. This is seen as an important skill to be able to integrate systems by their selves.

Many of the interviewees observe that vendor management skills should be developed. The process of managing a single vendor platform compared to managing a multi-vendor platform is very different. This requires much more cooperation oriented way of managing vendors, thus knowledge and skills must meet that criteria. Interviewees commented that contractual side between vendors is important. Clearly defined responsibilities should be implemented to the daily operations so that the vendor is acting appropriately.

This requires tight integration between a vendor and operations. The operational model used in the traditional platforms was not seen possible with the Telco Cloud platform.

Several of the interviewees have an opinion that internal communication is important activity, thus, a need exists for this knowledge. Internal organization is going to require more information than in traditional models. Different kind of information channels should be used for sharing an information. However, it was seen that this communication should not be a one-way stream but more as a dialogue between application users and Telco Cloud operations. This emphasizes social skills.

Deploying applications and services to the Telco Cloud platform is seen as a very work heavy activity because current applications are not designed for a cloud environment. This is raising the requirement for organizational understanding of what applications require from the platform level. Skills for the requirement engineering, testing and effort estimation were seen important. Furthermore, one of the mentioned knowledge areas is the overall architecture of the system. Architectural requirement on the high-level structure need to be understood. This is seen as a software level issue that can be mostly mitigated by using knowledgeable software architects and appropriate software engineering disciplines. If this practice is not followed, eventually a fragmentation and complexity are seen as emergent.

The on-boarding process is seen to contain a phase that collects all potential applications and their capabilities of being on-boarded to the Telco Cloud. This list of applications can then be used in the strategic planning phase to make selections of the investment areas.

4 Data Analysis

All collected data are analyzed and summarized after the transcriptions of the interviews. A few standardized analysis techniques are available for the qualitative research. The qualitative data analysis technique is used.

In the analysis phase, the source data is reviewed and different items mentioned in the transcripts are coded, categorized and linked together. The qualitative data analysis and research software called ATLAS.ti [90] is used for analysis purposes. Coding is done iteratively and the structure is built by analyzing the situation in the discussion. The important matter in a situation is the actual saying of the interviewee and what is not said. The qualitative data analysis and ABC structure methods are used also for analyzing the secondary data. The illustrative concept network diagram can be seen in appendix F. The qualitative data analysis and ABC methods are described in section 2.

The concept analysis network visualizes the formation of major categories in the analysis phase. The Telco Cloud can be seen as a focal point in the centre of the paradigm. Each coded item are compared with others on the outer layer and similar issues are either combined or brought together. The similar characteristics of certain items are used as a grouping categorization. These groups indicate some sort of logical relationship, but causal relations cannot be made except in a couple of rare cases.

During the analysis, three major categories emerge and further research is divided into those areas. (i) First, the Telco Cloud as a paradigm and structure of it. This part contains the infrastructure, hardware, location and VNF parts from the concept network diagram. (ii) Second, the financial cost structure of the Telco Cloud and comparison to traditional telco platforms. This part contains several part of the concept network diagram, i.e. the process requirements and cost structure categories. (iii) Third area is the Telco Cloud as a strategic capability for telecommunications operators. This part contains the strategic implications, organization and knowledge, on-boarding and multi-vendor environment categories from the concept network diagram. The overall research process can be seen in figure 1.

In the financial cost structure part activities, different cost items and pools are defined. Second, division between CAPEX and OPEX costs are made. The cost allocation bases are formed using analysis results from the Telco Cloud paradigm part. This new cost structure model is then compared to the corresponding model of a traditional platform's cost structure. The cost structure model is also evaluated using two cost level calculations.

In the last part, strategic and managerial implications of the Telco Cloud are analysed. This part contains regulation, business perspectives, knowledge development, on-boarding process and strategy part as an input. To analyse the domain, the qualitative data analysis method is used.

4.1 Telco Cloud Paradigm and Structure Analysis

The paradigm analysis reveals that several alternative objectives exist that the platform shall meet to improve its position compared to a traditional platform model. The Telco Cloud platform can be seen as an enabler for other services, thus it enables a platform business model and takes advantage of externalities [91]. The platform can utilize more automatic way of producing services and minimize manual work activities, thus reduce production costs in form of decreased personnel expenses. The shared platform, combined with generic resource pools can be seen as an enabler to develop and introduce new services faster to the market. Yet, prototyping and small scale testing becomes possible. Geographical distribution might improve service quality and service levels on average level. Furthermore, the consolidation of services expose the economics of scale benefits by dividing fixed sustaining costs of the platform to several services.

On the other hand, the technology base is still very immature. the study indicates that the OpenStack as a software technology is not yet ready for wider production use. Transition from a solid and proven technology to a new one is a risk that must be managed. One way to mitigate the risk is to have old and new platforms running side by side. However, this yields excess costs and cannot be seen as a long term solution.

When the platform is new, formation of a cost structure might seems to be ambiguous and some might consider the platform as a more expensive alternative. Hence, change resistance might be happening. On the other hand, when the new platform has been built, nobody want to leave it empty and organizations might unintentionally force services to a cloud model despite the fact that all applications are not compatible with a cloud model.

While the Telco Cloud concept is tightly associated to the telecommunications service production, each organization has to consider on case by case that what applications and services they actually are going to on-board. The platform can be seen as a mean to produce services for customers. Users are experiencing all those good and bad consequences of the transition. Operators' own business logic steer whether the cloud nature of the platform is exposed to a customer or not. In any case, certain is that the change in a production form cannot decrease service level of a service due to competitive and regulatory reasons.

No platform can survive in a company without adequate complementary assets, meaning i.e. processes and supportive organization. The analysis indicates that the transition from a traditional model can be seen mostly as an in-sourcing procedure, thus as a process change. This is due to a large role of a vendor in traditional platform models. The platform specification management, cloud layer development and operations are a few of those activities that must be introduced when moving from a traditional to the cloud model. Certainly several more are required, but those can be seen as such processes that are also required by traditional platforms. Hence, indications exist that the deployment of a Telco Cloud platform also affect how people are working due to changing processes.

One dimension that is revealed by the analysis is multi-vendor nature of the platform. There can be several software layers, the computing capacity can be produced by several providers and the support provider might be different than a software producer. The research indicates that the objective with this multi-vendor approach is to strive towards vendor independent situation. While the pursued goal is desirable, the increased need for a communication between stakeholders is evident. This inflates required work hours needed for vendor management activities and it also increases the overall complexity of a system. To manage all this, certain activities shall be expected from a provider. Especially the cloud layer provider should have means to respond to requests that a telecommunications operator has, thus have an experience on the field. Incidents and vulnerabilities might issue the whole customer base of a provider. Furthermore, in a multi-vendor environment is not expected that each vendor has exactly the same kind of testing environment as the operator has. A cloud provider has to consider how the quality assurance is carried out.

The platform structure analysis reveals that the Telco Cloud paradigm is in very close relation with the cloud computing and cloud service paradigms. Results indicate that characteristics such as a capacity on demand, location independent and resource pooling are found to be important in the Telco Cloud platform. However, to bring the platform to the level that meets standard telecommunications requirements set by standardization organizations and regulators, features such as enhanced power supply systems, advanced system security and monitoring measures need to be implemented. Furthermore, the application providers have to be able to provide a cloud capable software and architectures that meet platform requirements.

The analysis indicates that the platform core infrastructure is consisting of data centres, networks, server hardware, virtualization software and cloud layer software. Furthermore, platform requires supporting functions such as monitoring, orchestration and management systems.

Utilized data centres should not be chosen by random, but by coherent design logic. While distribution brings services closer to a customer, each regional DC node is decreasing the overall utilization of the Telco Cloud platform due to increased number of servers required for the cloud layer. However, by distributing services off from central sites, a regional DC can serve a smaller number of customers, hence also lowered regulatory requirements can be applied, which potentially results cost savings.

The analysis indicates that one of the main OPEX sources is the electricity cost. Thus, the per device electricity requirement and data centre PUE become cost drivers. Per device power requirement can be managed when the device is purchased by choosing models that consume less power per produced computing unit. The DC PUE value is mostly defined by the cooling system of a server room and power distribution methods. The DC48V electricity has found to be more efficient than the AC distribution due to fever voltage conversions needed. According to Caleb Garling [92], as much as 15 percent saving can be exploited by using a DC48V electricity distribution. The cooling efficiency can be improved by using methods, such as feeding waste energy for heating houses [93] or free-air-cooling [94], PUE can be improved and electricity consumption can be lowered.

Each DC must contain racks for devices and a redundant Uninterruptible Power System (UPS) device for the continuous electricity feed, a cooling system and security measures as described in FICORA's directive M54 [46]. A number of customers using some component defines the requirement for how long the battery capacity have to last in electricity outage situations. Thus, bigger DCs that are serving more customers are more expensive to build due to bigger UPS systems and battery capacity.

The hardware layer of an infrastructure contains separate network and computing equipment. Both of these can produce virtualized capacities to be consumed by upper layer applications. The actual technology which produces the virtualization layer is not found to be important in this study. However, more important is that the automation and orchestration should manage all these uniformly.

Virtualization and cloud layers, thus new abstraction layers compared to a traditional model, are expected to add software to the stack. A few of those discovered software components are server virtualization software, orchestration software, application life-cycle management software, a service provisioning interface, a cloud manager and the OpenStack. The OpenStack is the only one of the explicit product names mentioned in the transcripts because it was mentioned so many times during the interviews.

All these software components have several software licencing options available. A software can be acquired as a commercial off-the-shelf (COTS) software product, as a bespoken software from a service company or as a cloud software product from a cloud provider. In these options a company has to have a means to purchase acquired software and manage vendors. According to IAS38 [51], intangible software products can be considered as a CAPEX. It does not a make difference if the software is COTS or bespoke. However, a cloud software is typically charged in a pay-per-use basis, thus these costs are realized as OPEX for an operator. The difference is that instead of fixed predefined depreciation time, in the OPEX model the cost must be considered to continue forever.

A little bit different kind of approach for acquiring software is to use generally available open source software, which are typically licensed as a free to use. The first impression is that this is an inexpensive option. However, to use such a software, an operator has to have own software developers that are able to develop, integrate and support the software when needed. Furthermore, due to a lack of commercially supported QA process, an open source software might suffer in stability, security or performance. Thus, an operator has to invest also into extensive testing and QA methods. Hence, these extra activities are yielding more personnel expenses. The relative cheapness of an open source software is highly dependent on overall maturity and quality of it. However, this is highly ambiguous.

Finally, what comes to those actual VNFs, two view points exist to the topic. What VNFs expect from a platform and vice versa.

First, to introduce new applications to the platform, a company has to be aware of its services and applications. While this may sound trivial, it actually might be the hardest part of the process. As long as the application has not been on-boarded, the exact amount of required resources and development work is only an estimate. Hence, quite challenging is to estimate the feasibility of on-boarding at the first place. Furthermore, the line between a cloud-capable software and cloud-incapable legacy software is not strict line but more like an optimization problem. Hence, one option is to contract the on-boarding out. In this case is highly possible that a software partner is charging some premium of this ambiguity. In either case, these costs and risks are part of the learning costs introduced by a new platform.

Second, to build a capable service platform, strict specifications and standardizations should exist so that interfaces are kept stable and supported also in the future. Part of the design problem is that as long as the platform is a draft in a drawing board, a freedom to change characteristics allows flexibility. Deployment of the platform and first on-boarded VNF bind the specification down and all changes after that are very costly. Several options exist to overcome these. Instead of using a proprietary specification, open standards could be used. However, this decreases appropriability regime further and makes protecting IPRs even harder.

4.2 Cost Structure Analysis

As described in section 2.4, the ABC model is building on the concept of activities. Those activities are tasks, jobs and operations that people or machines have to do. The first part of this analysis is to identify those activities. Those actual activities are categories for more specific tasks, events, incidents and processes that were mentioned in the interviews.

4.2.1 General Activities and Allocation Bases

The analysis of each activity, task and event from the interviews reveals 13 different categories. All cost sources, including personnel related costs, are applied to the categories. Relations between categories are studied and linking between categories are defined in form of an allocation base. All 13 categories are listed here with their content and analysis. These activities cover several processes that an organization has to execute to build, maintain and develop the Telco Cloud platform. However, in this analysis important factors are those that make difference between the traditional model and the Telco Cloud model.

- Platform activities
  - *Hardware installation* is an activity to introduce new servers, network switches and other required hardware when a new DC is been built or capacity expansion is required for existing one. The cost allocation unit is number of servers installed. This is a one-off activity that is realized only when something new is been built. In the Telco Cloud model this activity is carried out when addition capacity is required or new DC is been built. In the traditional model this activity is carried out when a new application is been deployed.

- *Asset management* is mostly due to CAPEX depreciations, thus a software or hardware asset amortizations. This does involve also personnel costs if a work activity has been capitalized during the development phase.
- *Cloud development* is an activity to develop the cloud manager, automation, virtualization, provisioning interfaces and integrations to other systems. This activity contains also costs of continuous integration team or other software development activities related to the platform. This is on-going activity that requires constant amount of work hours per month.
- *Configuration management* is an activity to ensure that all versions and life-cycle phases of components are recorded and managed coherently. This information is part of the centralized configuration repository. This activity can be mostly automatized but there might be some manual tasks. This information can also be used for real time cost analysis and for charging external parties using the platform. The configuration data is also using as a base for any platform simulation.
- *Proactive platform maintenance* is to keep the platform functioning properly with proactive measures. This contains proactive defect patching planning, security threat monitoring, life-cycle management, problem management and monitoring. This is on-going activity that requires constant amount of work hours per month.
- *Capacity management* is to monitor the actual usage of the hardware platform such that also redundancy capacity is secured on the case of failure. The capacity planning, capacity monitoring development, forecasting, geographical coverage planning, measuring and road-mapping is part of this activity. This is on-going activity that requires constant amount of work hours per month.
- *Server operations* cover all tasks and costs related to continuous operations of the hardware platform. Costs such as electricity and cooling, facility costs, hardware recurring maintenance cost, networking cost and incident costs, including work hours related to this activity. This is on-going activity that requires constant amount of work hours per month.
- *Software operations* cover all tasks and costs related to continuous operations of the software platform. Costs such as recurring software licenses for cloud, virtualization, automation and management systems. Also all other software maintenance costs, small configurations tasks and scripting work hours are booked here. This is on-going activity that requires constant amount of work hours per month.
- *Platform specification management* activity contains tasks such as creating and maintaining a clear specification of the platform for VNF applications. This is mainly a one-off activity that is realizing only when something new is been built, but there might be cases when a platform update triggers a need for updating the specification.

- Application specific activities

  – *Application on-boarding* activity is to introduce new applications to the platform. This includes tasks such as the software requirement engineering, software development, testing, validation, integration and project management. This is per application activity that is realizing only when a new application is been introduced to the platform. There might be cases when a vendor's software upgrade also triggers this activity. In the early phase of the platform is expected that an operator pays most of the on-boarding costs. When the Telco Cloud paradigm matures is expected that a software vendor is taking care of the most of the on-boarding and integration costs due to a standardization.

  – *Application development* must be done if the platform specification is changed due to a component update. This triggers a need for an application and service development and testing activity. The intention is also to ensure that changes in the platform does not cause any incidents. This activity can be considered as on-going activity that requires constant amount of work hours per month.

- Organizational activities

  – *Human resource management* activity is to ensure that each time new person starts, the person is introduced and trained to his duties. This consumes considerable amount of time. Furthermore, when new features are introduced or existing features are changed, a need exists for training of existing personnel. This activity can be considered as an on-going activity, although the work is not constant, it still consumes certain level of hours on the average level. Certain turnover in a development and operation personnel is considered as normal.

  – *Internal and external communication* is important to keep a linkage between platform development-operations, user organizations and external stakeholders such as vendors and regulators. This activity covers software and hardware vendor management tasks and collaboration with others. Furthermore, internal communication such as bulletins and platform support for others in the organization is part of this activity. Yet, contribution to a strategic planning is causing work tasks. This is on-going activity that requires constant amount of work hours per month.

These 13 activities are functioning as cost pools for all platform related expenses. Furthermore, total of four individual cost allocation base classes are functioning as drivers. These allocation bases share cost pools to different cost objects.

- *Total number of applications* divides cost pools equally to all installed applications. These costs can be considered as a sustaining cost of the platform. Activities that are using this allocation base are the cloud development, proactive platform management, platform specification management, human resource management, yet internal and external communication.

- *Number of configuration items* allocation base divides cost pools according to number of configuration items recorded in the repository. For example if a service is using a lot of virtual servers or has several concurrent configuration and software versions, the configuration management activity yields a lot of costs.

- *Total amount of memory* allocation base divides cost pools according to cumulative usage of memory capacity in the platform by applications. Activities such as server and software operations, capacity management, hardware installation and asset management are allocated using this base. It should be noted that the asset management activity allocates monthly only the depreciation of that month.

- *Direct costs* are directly allocated to the corresponding product or service. Activities such as the application on-boarding and application development are allocated using this allocation base.

All these activities and cost allocation bases combine total cost for cost objects. In this model is assumed that one cost object is representing also one service produced by the Telco Cloud platform.

4.2.2 Analyzing Cost Structures and Their Differences

The cost structure of a Telco Cloud constructs on previously mentioned activities. All activities does not require own cost allocation base, instead several activities can share the same cost allocation base. The structure of the cost model can be seen in figure 10.

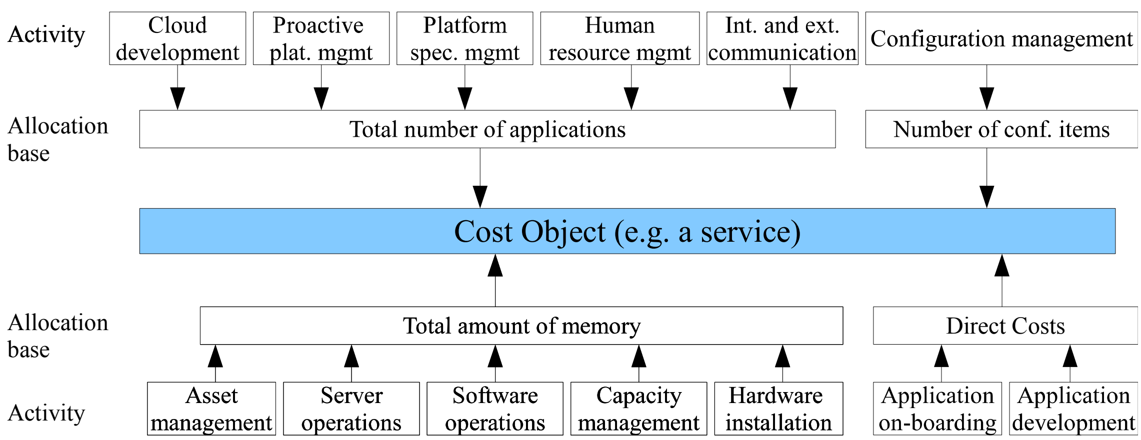

Figure 10: Activity-based Costing model for the Telco Cloud platform

A traditional platform model contains almost all same activities that the Telco Cloud model has. The traditional model does not contain cloud development activities. The capacity planning is more straightforward due to an application dedicated platform. Furthermore, the collaboration with vendors can be streamlined because one vendor provides the platform as a turnkey solution, in which all hardware, software and applications are already installed and tested prior the delivery to a customer. On the other hand, the analysis indicates that in a turnkey solution, the cost of that platform is easy to predict and forecast. Furthermore, the capacity management and measurement activities are on the platform vendor side, thus activities are consuming fewer operator's resources.

Hence, a traditional model platform's design, implementation and part of the production are actually outsourced in the case company. Although the traditional model is technically quite similar with the Telco Cloud despite the cloud layer, the process and management of the system is totally different.

Two major differences exist between a traditional and Telco Cloud models in the ABC cost structure. (i) In traditional model all platform related costs are direct due to the application dedicated platform. (ii) Traditional model does not contain the cloud development activity. On the other hand, the Telco Cloud model brings some process capabilities that need to be in-house. For example a capacity management, platform related planning, development and operations are activities that need to be taken care of.

As can be seen, in the Telco Cloud model, all cloud development costs are allocated using equal share per application. Hence, if the number of application is small, relative allocation per application is high. Thus, in the beginning, the Telco Cloud model is more expensive than the traditional model. The Telco Cloud model shall be seen as a long term investment.

From the cost structure can be seen that those activities that are using allocation base *Total number of applications* are forming a recurring fixed cost for an application. Because every on-boarded application is going to get a share of it and no correlation exists between the actual usage of a service and a cost. However, when the number of applications grow, the allocation of these costs are going to decrease due to increased allocation base. On the other hand, activities that are using allocation base *Total amount of memory*, are getting increased costs when the usage of an application grows, thus the cost is variable. Hence, when the utilization of the platform increases, all applications are gaining benefit.

Table 1 contains the comparison and the summary of activities, drivers and a short reason why the model is more cost-effective than the other. The driver column describes the primary factor in the Telco Cloud model that is correlating with cost of the activity and a causal relation exists from a driver to costs. A node, server, DC and application counts are linear factors that are correlating directly to costs. Complexity driver describes characteristics of a cost such that the cost is considered fixed but the cost is dependent on overall complexity of the system. Operational personnel and stakeholder counts are linear factors.

4.2.3 Analyzing Relative Cost Levels of Platforms

Amount of costs for each activity are estimated to simulate the cost allocation behaviour in the function of the node count. Due to lack of exact accounting records in the case company, estimation is carried out instead. Several assumptions are made during the estimation. Most these assumptions are based on experts' judgement. Persons involved in the Telco Cloud project contributed these estimates.

Technical specification values are collected from literature sources and from vendor specifications. The average server and network switch electricity consumptions are estimated using the tool released by the hardware vendor [95]. The average DC PUE of 2.0 was used as a compromise [96].

These estimates are not fully accurate due to the high level of averaging. Thus, these estimates should not be used as a base for any quantitative research. Instead,

Table 1: Comparison of the Telco Cloud and a traditional platform cost structure

Activity	*Driver*	*TP*	*TC*	*LC*	*Reasons*
Hardware installation	Node count	X	X	TP	Fewer sites in TP
Asset management	Server count	X	X	TC	Fewer servers in TC
Cloud development	Complexity	-	X	TP	No cloud layer in TP
Configuration management	Complexity	X	X	TC	Automation reduces manual work
Proactive platform maintenance	Complexity	X	X	TC	Fewer platforms to manage
Capacity management	Server and DC count	X	X	TP	Dedicated platforms easier to handle
Server operations	Server count	X	X	TC	Fewer servers in TC
Software operations	Server count	(x)	X	TC	Fewer servers in TC
Platform specification management	Complexity	(x)	X	TP	Dedicated platforms easier to handle
Application onboarding	Application count	(x)	X	TP	Dedicated platforms easier to handle
Application development	Application count	X	X	TP	Dedicated platforms easier to handle
Human resource management	Operational personnel count	X	X	TC	Fewer personnel required in TC
Internal and external communication	Stakeholder count	X	X	TP	Dedicated platforms easier to handle

Legends: TP = applicable for traditional platform model ; TC = applicable for Telco Cloud model ; LC = lower relative costs in ; X = The platform contains costs related to this activity; (x) = The platform contains minor part of costs related to this activity ; - = The platform does not contain costs related to this activity these estimates should be considered as qualitative indications of the phenomena. The equations and initial values for the calcucations can be seen in appendix E.

Figure 11 illustrates estimated sharing of the costs between different activities on the function of the node count. When the number of nodes is small, the relative share of the Cloud development activity cost is high. When the number of nodes increases, the Asset management activity cost becomes the major. Another major cost is the Software operations, i.e. commercial cloud license costs; and the Server operations, i.e. electricity costs.

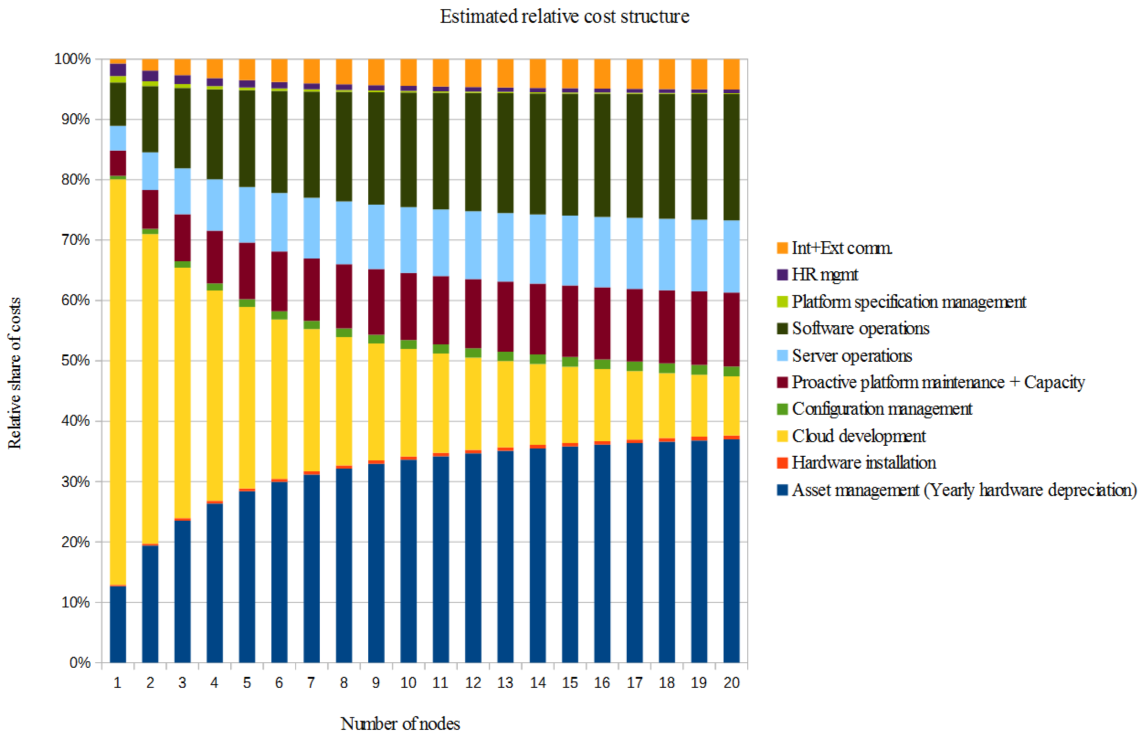

Figure 11: Calculated cost share between activities

Another cost estimation is also carried out during the analysis. The average cost per application decreases very quickly when the number of applications increases in the platform. The illustrative graph can be seen in figure 12. This indicates that the economics of scale realizes in this model.

A traditional application dedicated platform model does not contain costs related to the Cloud development and Cloud licensing. On the other hand, required number of servers is higher due to the redundancy requirement and lack of statistical multiplexing leverage. If the same assumptions as in the Telco Cloud model are used, the calculated average annual cost per application is 113.000 euros per application in the traditional model. The interesting value is the break-even point between the traditional and Telco Cloud cost models. With these estimations, the break-even point is when the number of applications reaches seven. This corresponds to 66 servers. Thus, relatively small number of applications are sufficient to justify the costs of the cloud layer.

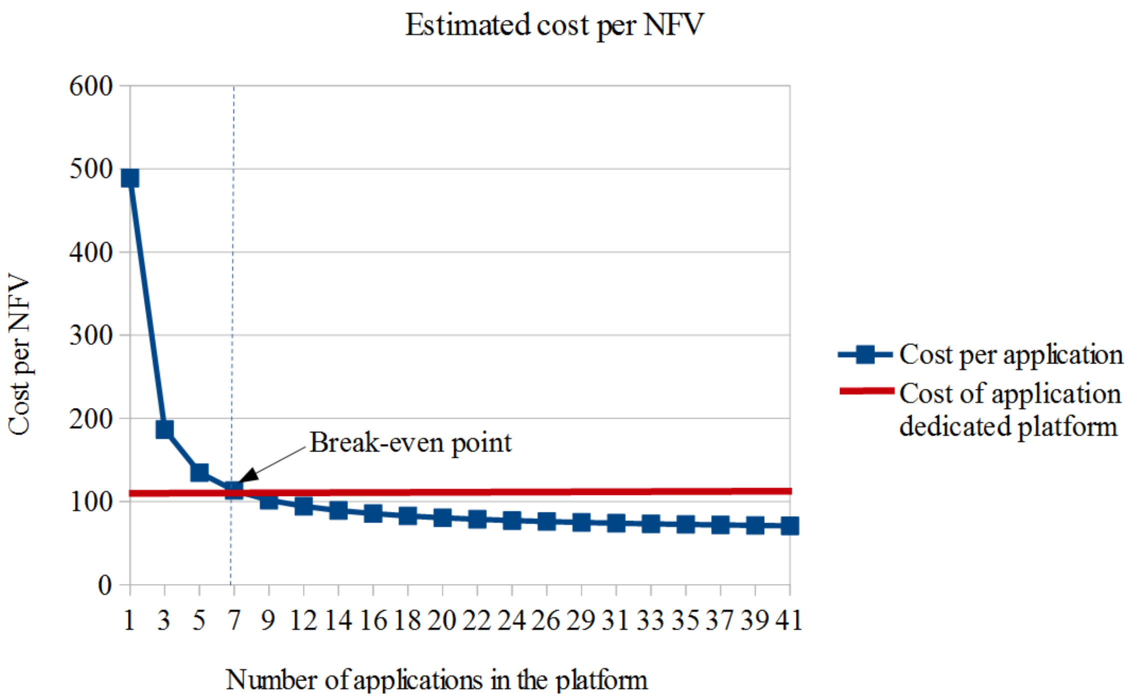

Figure 12: Calculated average cost per an application

When the application count reaches 40, the average cost per application is 71.000 euros in the Telco Cloud model. Thus, when compared to the traditional model the calculated model indicates that the saving is more than 30 percent.

Other scholars and commercial vendors have studied costs of a data centre operation and cloud production. These estimations are focusing on running a large scale public cloud production [97][98][99]. These studies are very heavily concentrating to costs related to physical items, such as hardware, electricity and cooling. These estimates are not directly comparable to the results made during this study. The differences can be explained by different assumptions between calculations. However, these studies indicate that server hardware depreciations are actually the major part of the costs in a large scale data centre. For example, Bias [99] estimates that the ratio between a server hardware depreciation and electricity consumption is four to one. This is exactly the same that was observed during this study.

5 Telco Cloud Deployment Guidelines

Several Telco Cloud deployment related items are observed during the analysis. Some of the most important topics are covered in this section. These guidelines are constructed from the qualitative data analysis results and using literature sources. The items are structured into the form of strategic capability. Starting with competences and following with the resource-based view. The strategic capability model is described in section 2.6.

5.1 Competences

Several areas of competences are required to master the Telco Cloud platform. Existing services need to be transformed into a cloud model. Personnel knowledge need to be developed and different stakeholders need to be managed in a new way. These items are discussed in this section.

5.1.1 Application On-boarding Process

The purpose of the application on-boarding process is to evaluate, develop and introduce new applications to the Telco Cloud platform. The process as such is straightforward and generic. The illustrative process graph can be seen in figure 13.

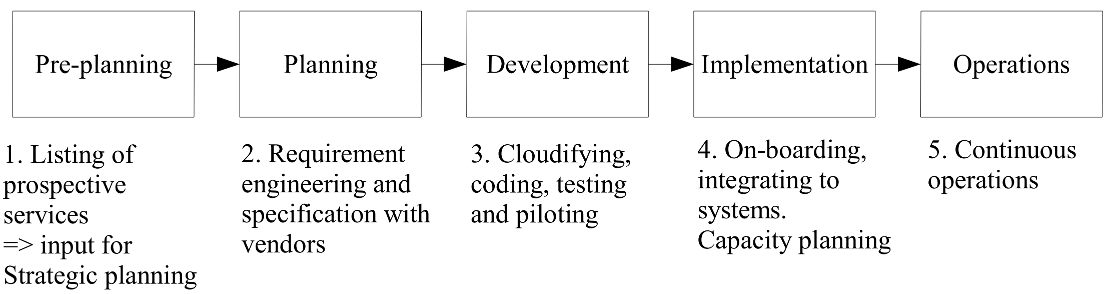

Figure 13: Application on-boarding process

Objective of the pre-planning phase is to act as a gatekeeper for all prospective applications before the actual on-boarding planning starts. Especially in the early phase of the platform, strict policy should be retained so that only those applications that really fit to the platform are allowed further to the process. The learning process is going to take time. Important is that knowledge development process is in sync with the application on-boarding process.

In the pre-planning phase, cost calculations are created or updated for a traditional platform. Then those calculations are compared to the Telco Cloud cost calculations to analyze financial feasibility of the migration. Furthermore, initial discussion with the software vendor must be carried out to analyze technical feasibility. The platform specification document describes the requirements that the platform is setting. The software vendor should ensure that the software they are providing complies with the specification. If the service transfer is found to be plausible, then the application is added to the short-list of possible applications. The strategy planning process takes care of deciding which applications will be on-boarded and on which time frame. Platform development specialists should assist the strategy planning so that the capacity, personnel and development requirements are identified correctly and financial budgeting can be planned appropriately.

In the planning phase, the RE process is important part to find all functional and non-functional requirements of the service. The RE is also solid part of the software engineering discipline, as described in section 2.5.1. The mode of the development project is going to define if the planning is separate phase, as in a plan-driven project model, or concurrent phase, as in Agile methods. The software vendor should be kept involved so that they can contribute in the early phase of the process and they can acquire understanding of the functional and non-functional requirements.

In the development phase, the most critical part is to transform the application to the cloud model. The service capacity scaling should be done using a virtual server replication. This is called a scale out model. The redundancy should be on the application level, thus the application should not trust the availability of an underlaying infrastructure. Furthermore, there should be an orchestration system that compose any required activities. Before the on-boarding process proceeds to the implementation phase, the code base and features should be tested as described in section 2.5.2. Furthermore, good practice is to engage pilot customers to the development phase so that possible non-functioning features can be spotted as soon in the development phase as possible.

Although careful selection methods of an application are used in the pre-planning phase, it might be possible that the application reveals to be a non-cloud compliant. In this case continuum of the whole project should be re-evaluated and terminated if alternatives are not found.

In the implementation phase, the new NFV application is installed to the Telco Cloud platform and integrated to orchestration engines. In this phase is mandatory to ensure that enough capacity is available in the Telco Cloud platform. The platform should able to sustain also a full site outage and other emergency situations. There should be a check list available so that critical success factors are inspected. This should be carried out before the final decision of introdution to production is made. Especially service monitoring and full scale disaster recovery plans should be considered mandatory factors.

Operation and implementation phases should progress concurrently so that the operations phase becomes accountable smoothly and discontinuities between phases are not caused. The continuous operation phase covers for processes that are required to keep the system functioning. For example capacity planning and proactive platform management activities. As described in the section 2.5.3, the software evolution and configuration management phases are crucial to handle changing requirements of a system. Thus, these processes should be implemented as early as possible.

5.1.2 Knowledge Development

The competence development should be carried out as a continuous process instead of one-off activity. To ease the process, appropriate knowledge development tools shall be applied. For example Bhatt [100] proposes the knowledge development cycle model, which builds a knowledge in phases such as creation, adoption, distribution and review. Furthermore, important is to understand the distinction of the tacit and explicit knowledges, as well as organizational and individual knowledges. While a tacit knowledge is important for creating non-imitable competitive advantages, tacit is more challenging to manage and is highly person related. On the other hand, an explicit knowledge is easier to manage but also easier to copy between companies. [101]

As was already seen in section 4.2, the traditional production model emphasizes responsibility of a vendor. Thus, most major platform related activities are done by the vendor. Hence, most of those knowledges are also located in a vendor company. In the Telco Cloud model, an option is to contract out most of the activities. This results an out-sourcing of the knowledge, thus, it avoids the need to in-source the knowledge at the first place. However, when building a long-term strategic capability, more valuable for the company is to keep most of the critical information inside the company.

According to Cohen and Levinthal [102], two categories of knowledge sources exist that a company shall absorb, internal and external. To adopt external knowledge, a company can use active or passive methods. In passive method a company screens external information and adopts the information that the company finds important. One tool for this is the technology watch process [103]. External knowledge can also be acquired using active methods such as partnering or alliances [81], or knowledge brokering [104]. While beneficial is to remove any unnecessary barriers between parties for activating knowledge sharing, crucial is to be able to protect a confidential information and unique knowledge using appropriate methods [105].

On the other hand, an internal knowledge development is relying heavily on communication between subunits of the organization [102]. To support knowledge development, managers of a company have to consider if the organization structure is supportive. Structures that emphasize knowledge sharing regardless of location, division or function are found to be effective [106].

5.1.3 Compliance Management Process

Compliance management is a process to manage behaviour of the company according to rules set by internal or external authority. These rules can be seen as constraints. [107] In the context of the Telco Cloud, a company has to be compliant with a regulatory and legislative matters. Furthermore, several internal policies and rules may exist that must be also followed inside a company, i.e. platform specification.

As discussed earlier, the Platform Specification is one of the Telco Cloud platform specific activities and the platform specification document is the output of the activity. Expected is that the platform is going to contain more than hundred of different applications with different security constraints. Thus, crucial is that the specification is explicit and all applications are following it obediently. If compliance fails, it might result fragmented platform environment and multiplied costs. Thus, security breaches and reduced cost-efficiency.

The platform specification document should be constructed using standardized RE process and consequent documents should be versioned and approved using a change management process. This way the interface stability can be guaranteed for applications and the system can be validated as a whole. The versioned specification document should be communicated to all relevant stakeholders.

The regulation directives for the telecommunications services were made during the era of traditional service platforms. Due to this legacy, most of the regulatory directives are leaning on hardware device level specifications. The Telco Cloud and more generally the NFV concept are going to trigger a need for a review of regulation directives. The platform specification document should cover all functional and non-functional requirements from regulators' directives. On the other hand, the platform specification document should guide how the redundancy, reciliency and security should be implemented in the Telco Cloud.

One way to enhance the compliance management process in a regulatory driven company is to adopt the policy-based and model-driven regulatory compliance management framework. It eases to identify, model and enforce solution for any issues that must be supervised. [107]

5.1.4 Financial Competences

The capacity management process can be seen as a financial competence. It produces a guidance for an investment process by showing how the capacity is actually utilized and when to purchase more. The ability to meter the platform and forecast the usage are tools for the process. The process also produces a reporting information of the usage of the platform that can be used as a Balanced Score Card (BSC) report.

Another important competence is an ability to create roadmaps which are used in financial forecasting and strategy planning processes. The roadmaps should guide transparently expected costs of different scenarios.

5.2 Resources

While competences create the base *how* things are done, the resources part answers to the question *what*. Assets and stakeholder co-operation in the context of the Telco Cloud deployment are discussed in this section.

5.2.1 Assets

An incumbent operator might have hundreds of different services and applications in its environment. Any those services can be seen as a candidate for an application on-boarding. Hence, those also include a potential cost-saving. When this is combined with applications expected LRIC development and a service life-cycle, an optimal on-boarding prioritization can be created so that maximized savings are realized.

Indications exist that a company has to do a relatively large initial investment when the Telco Cloud capability is been built. The pay-back time of the investment could be several years. Thus, the company has to have a cash-flow to sustain these development costs. The funding can be acquired using a loan, income financing or co-creating with external investor.

The telecommunications and software operator markets are on the regime of the low appropriability. Thus, very hard is to protect innovations using patents or trademarks. Technological innovations become quickly commodity and ability to gain competitive advantages using those technologies vanishes quickly. However, possible is to use all those company assets as a unique combination that nobody else have. When this is combined with the complementary assets of the company, such as processes and brand, these commodity assets can be leveraged after all.

In the case of the Telco Cloud, this means that the network effects of consolidating applications could be exploited. Furthermore, a telecommunications operator has typically several DCs. Most of those are regional DCs near to customer. By distributing services to these regional DCs, the average number of customers per node can be lowered. Hence, this opens an opportunity to transfer services to lower regulatory level DCs and reduced DC infrastructure investments can be exploited.

Furthermore, one of the assets that a Telco Cloud operator can leverage is its own network's management plane. It opens an possibility to fine tune QoS features that are not normally available for other service providers. [16]

5.2.2 Stakeholders and Co-operation

The traditional platform model relies heavily on external vendor resourcing. In Telco Cloud model, a company has to choose whether to in-source resources by recruiting more staff or keep resources external by contracting out. However, recommended is that the actual substance knowledge and core competences are kept inside the company so that company can develop the strategic capability as close to the company as possible.

Anyhow, a need exists for close relationship between an operator and different software vendors. Recommended is that operational steering group is formed for each vendor. The group consists of specialists from the operator side and from a vendor side. The intention is to ensure continuous information and knowledge exchange between parties. These steering groups are also functioning as gatekeepers toward vendors.

5.3 Formation of a Competitive Advantage

As described in section 2.6, competitive advantages are building on strategic capabilities and on a well-chosen generic strategy. To form a strategic capability, right combination of resources and competencies are required.

The study indicates that the emergence of a strategic capability takes time. Knowledge, technological and process development actions improve capability gradually. Especially technological development can be expected to proceed quickly only if a major invention, called technological discontinuity, is happens. However, a technological advantage is hard to gain in the telecommunications market due to low appropriability regime.

A common wisdom is that a company cannot choose both cost-leadership and differentiation strategies at the same time and still success. This is called a stuck in the middle phenomena. [78] Hence, a risk is to use Telco Cloud platforms for both cost-leadership and differentiation strategies simultaneously. However, possible is to utilize the Telco Cloud for focus strategy. In this scenario nodes are distributed and optimized for different customer segments individually. This fragmentation lowers investment efficiency, but it enables wider range of applicationa that can be on-boarded to the platform.

5.4 Critical Success Factors

The data analysis reveals several critical success factors (CSF). Those are setting the minimum level which must be achieved so that the Telco Cloud platform could be considered successful. The services that are used as a reference in this case study are SMS and VoLTE/IMS. During the analysis, all labeled items are reviewed, classified and categorized. The categorization reveals four individual groups; functional requirements, process related, organizational and cooperation with stakeholders.

- *Functional requirements* are factors that are concentrating on service availability and quality. Several factors indicate that the application on-boarding process has to have some quality control mechanism to check if these factors are realizing or not. A few of these factors are; the service redundancy on application level; high service availability; a security on high level; independent sites; the packet transport network must be very resilient; a geographical distribution of services are considered as a critical; and legacy services are setting the level for service and quality level expectation by customers. These factors are quite straightforward to interpret and measure, thus also report.

- *Process* related factors contain four major themes; capacity planning process should be able to assure that a redundancy capacity is available also in the full DC outage situations; a testing and validation process must be thorough so that errors can be isolated from the environment before those are causing service incidents; service and platform monitoring must be high quality; full coverage disaster recovery plans must exist.

- *Organizational* category contains three themes. The organization model should support functional way of working instead of one team per service model. Responsibilities between teams must be clear and agreed on. The organizational and individual level knowledge development, including knowledge transfer and information sharing, are criticals to ensure cross-technological and cross-functional skills.

- *Cooperation with stakeholders*, tight collaboration and co-operation between organizations and can be considered important. Vendors must be able to respond quickly to security vulnerabilities. Business units need support from the Telco Cloud platform development teams to take advantage of the new platform.

Although all listed CSFs are important, there certainly are some preferences between these in importance. However, this study do not reveal this information. Thus, an opportunity exists for further research in form of a preference survey.

5.5 Other Considerations

The study reveals several other deployment related considerations. A few of the most important are mentioned here.

Based on the findings of the study, complexity of a system has effect how much each activity requires work time. All work time estimates are made so that the complexity can be kept on a low level. Thus, integration between different components should be a simple task to execute. Hence, knowledge that help to simplify systems are required, i.e. APIs, modular structures and abstraction. On the other hand, there should be an individual and organization level capability to understand comprehensively of the application and platform co-operation. One of the knowledge development's objectives is to support proactive maintenance and problem management activities.

On the other hand, while the overall capacity is highly distributed in the Telco Cloud platform, the capacity management activity requires a forecasting model. This model should be linked to the application on-boarding pre-planning phase, working also as a link to the strategic planning and implementation phase. Each company has to build appropriate business planning measures that provide a driver data for the Telco Cloud capacity forecasting.

The study indicates that the transition from traditional platforms to the Telco Cloud platform is going to result contractual change with vendors. In a traditional model, the contractual liability of a vendor has been relatively large. This is not necessarily the case in the Telco Cloud model due to several smaller component providers. For some companies this might be an issue. Thus, this item should be escalated for the top management team resolution.

One more consideration is to be made. All major mobile network operators (MNO) have mobile virtual operators (MVNO) in their networks. When the Telco Cloud is being deployed, MNOs are turning the network rental business to the cloud model. Virtual operators are renting a network and cloud capacities. Hence, this new set up may provide new business models and business opportunities for MNOs. This study does not contribute a model for this but urges operators to start planning such a model.

6 Discussion and Implications

The linkage between theoretical frameworks and findings from the empirical research are discussed in this section. Characteristics of the Telco Cloud concept and the structure of it are presented. Second, the cost structure is discussed further.

6.1 Telco Cloud Paradigm

The literature review reveals that the Telco Cloud is rather new concept. It can be said that the Telco Cloud is still in a pre-paradigmatic phase, thus the concept has not fully settled yet and several competing variants are available. Different commercial vendors are trying to seize the opportunity to become the dominant design holder and reach the market dominance. This also opens opportunities for operators to be part of the standardization work. However, the Telco Cloud paradigm will be fixed when the end of the era of ferment reaches. Before that a space for diversification is available.

Several scholars have defined their own version of the Telco Cloud concept [13][15][16]. Three identified characteristics exist that are common for the all definitions. All definitions are basing the Telco Cloud on the cloud computing model. The NIST definition of the cloud computing is used as a reference [10]. Scholars define the Telco Cloud so that it serves a telecommunications service provider to consolidate different platforms. The consolidation is mostly seen to happen in the level of a service and a network element layers. Thus, hardware is not seen that important. Furthermore, introduction of virtualization and high level of an automational enable flexibility. The cost-efficiency can be improved by leveraging abstraction and reducing manual activities. These same characteristics were also found during the empirical part of this study.

Structure of the Telco Cloud model presented by this study can be seen in figure 14. Characteristics that the concept contain are

- distributed computing capacity platform that is using the Cloud Computing model,
- for services with high quality and performance requirements on the telecommunications area,
- meets regulatory requirements,
- provides standardized interfaces and
- leverages high level of automation.

This study proposes new definition for the Telco Cloud paradigm. *The Telco Cloud is a distributed cloud computing platform for telecommunications services. The platform virtualizes network functions and provides quality, performance and feature levels that meet the market and regulatory requirements.*

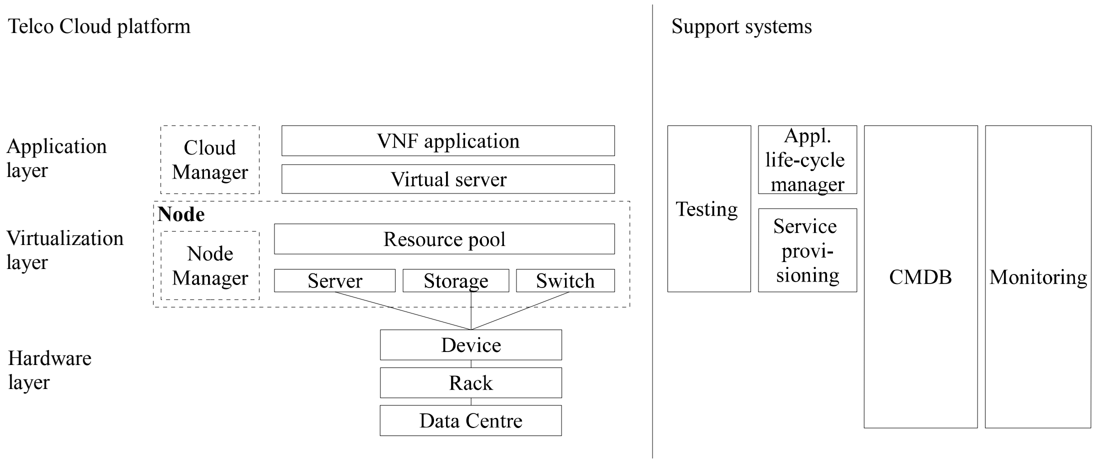

Figure 14: Structure of the Telco Cloud

To elaborate more on the structure, some items related to the structure are discussed further.

During the interviews no systematic naming for the data centres were found. On the other hand, Krzywda et al. [13] proposed names the Proximal DC for sites that are near customers and the Remote DC for central sites. This naming is found to be counter intuitive. Thus, this research proposes naming *Core DC* for a site that is in a central position and *Regional DC* for a site that is serving customers on some geographical region. A core network connects different DCs. Actual cloud resources are located in different DCs. Figure 15 illustrates the generic site structure. The interconnection to other physical infrastructure providers' networks can be also introduced if additional remote DCs are required.

Virtualization layer contains logical sub-unit called a node. The term node has been originally introduced by the commercial vendor [14] and after that it has been inherited to different models. A node is an autonomic container that has servers, switches and storage devices. Server, storage and network virtualization create resource pools that are controlled by the Node Manager. All devices of the node are located inside a same rack. Each DC may contain several nodes. Nodes might be distributed to several Core- and Remote-DCs for distribution and redundancy purposes. Hence, the size of a node defines also the incremental cost to introduce new capacity. When smaller nodes are used, smaller increments can be made, but in this case the relative share of the cloud layer becomes significant. However, when larger node size is used the overhead of the cloud layer is minimized but incremental investment requirement is larger. Single right level does not exist, but each infrastructure provider has to define their optimal level that meets their requirements.

The application layer contains all virtual servers that are running on top of the virtualization layer. The Cloud Manager requests resources from Node Manager for a virtual server, storage or network resource. The Cloud Manager also controls a VNF application provisioning and un-provisioning functions. While all underly-

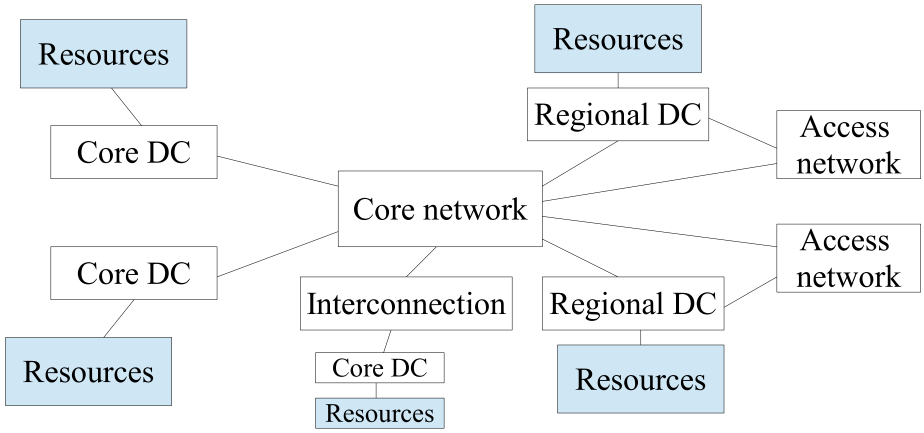

Figure 15: Overview of the Telco Cloud site structure

ing hardware are redundant and virtualization brings redundancy to the system, it should be noted that the Node Manager and Cloud Manager become as critical components for the system. Both of these components should be designed to be highly resilient for any infrastructure failures and the Cloud Manager should be redundant between sites. Furthermore, to ensure that the software complies with these requirements, testing and validation methods should be used continuously.

The Telco Cloud model contain also several support systems which fulfil the system. The monitoring system watches the platform from the hardware to the application level. This end-to-end visibility is crucial to get a proper view of the service state. A configuration management database (CMDB) contains the repository of all physical and virtual components that the system contains, including all software versions of applications running in virtual servers. The application life-cycle manager controls which version of a service application is running on what node and for what customer segments. This enables piloting and running several versions concurrently. Service provisioning module creates the service abstraction layer when resources are provisioned for legacy applications. The testing module tests the system and especially the application layer so that it is compliant with the specification. Testing is in tight integration with continuous integration tools if a company is using continuous deployment model.

While this presented model is compatible with the stakeholder model presented by Taleb [15], in section 2.2, some more stakeholders are proposed. As is found out in the analysis phase, section 4, that an operator has options to contract out the application on-boarding. In this case, the Virtual infrastructure, cloud service and service provider layers are still operated by the operator, but each application on the service provider layer might be on-boarded and operated by a different application management service (AMS) provider. Typically the AMS provider is the software vendor's service unit.

6.2 Cost Structures

As can be seen in section 2.4, the cost structure in the ABC model is based on activities. The Telco Cloud related activities were defined in section 4.2.

Analysis indicates that expected savings are up to 20 percent of OPEX costs and up to 30 percent of CAPEX costs. Additionally, the cost model simulations indicate that the total saving could be up to 35 percent. However, no facts are yet available in form of a quantitative multi-case study. Thus, these are just highly speculative estimations. Furthermore, common reference for cost level is missing. Thus, each company has to calculate the expected savings by their selves. The calculation method is described and evaluated in section 4.2.3. However, at this time, organizations are lacking this information, thus, a couple of years are required before the data could be available. In this research all figures are estimates. Furthermore, it should be noted that this cost structure purposefully exclude any other administrative costs that are not directly related to the Telco Cloud operations. In real world implementations of this ABC model, those costs should be also included.

While in a traditional platform model the SRIC and LRIC keep quite constant due to static nature of the platform, in the Telco Cloud the dynamic nature is actually quite strong. The network effects in the platform enable lowered production cost for all services when a new service is introduced to the same platform. Furthermore, while the application layer is detached from the hardware layer, the life-cycle management process can optimize the hardware layer independently. Even the cloud layer can be replaced if interfaces remain as specified. This modular and standardized model brings several benefits.

All identified activities related to the Telco Cloud platform are described in section 4.2. These same activities are also found to be relevant for the traditional platform cost structure. Nevertheless, in the traditional model some activities does not have any costs in the cost pool or does not cause any work activities. It can be seen that there actually are some benefits that can be achieved when using the Telco Cloud cost structure.

Findings of the study indicate that in a traditional platform model no synergies exist between application dedicated hardware, due to the fact that each application requires own rack of servers. CAPEX costs are fully allocated for one cost object, thus, for single application.

When application dedicated platforms are used, a redundancy capacity must be allocated for each platform separately. Hence, when the number of applications increases, also the number of servers required for redundancy becomes larger. The efficiency improvement in the Telco Cloud can be gained by consolidating redundancy capacities and taking advantage of the statistical multiplexing in a CPU and memory utilization. In the Telco Cloud platform, all applications are sharing a common redundant capacity. Hence, this results improved investment efficiency.

By inspecting the cost structure (figure 10) it can be seen that when the number of servers is small and depreciation costs are small, the Asset management activity cost pool is also small. Same applies for the Server operations cost pool, which contains mainly electricity costs, and Software operations cost pool, which contains infrastructure and cloud layer software licenses and maintenance costs. Thus, these cost pools are variable costs in the scope of the platform.

On the other hand, by looking table 1, it can be seen that the Cloud development activity is not present in the traditional model. Hence, the Cloud development activity costs are adding costs compared to the traditional model. The cost allocation base for a Cloud development activity is the number of applications, thus to keep per application cost low, the number of applications must be high.

Finally, when combining characteristics of capacity usage-based variable cost and fixed development effort-based fixed costs, it can be concluded that when the number of applications and nodes are relatively large the benefit of having the Telco Cloud is relatively big and the cost of the Cloud development activity is relatively small. Hence, it can be said that a benefit on the cost structure level exists when the Telco Cloud model is used.

The cost structure as such can be seen as a non-operational tool for analyzing the behaviour of the platform. Some implications can be derived to the operational level from this cost structure. As was seen earlier, in a large scale operation, the biggest cost source is hardware and software asset depreciations. Hence, to ensure a productively efficient market, an operator has to make sure that the number of servers are kept on a low level. This can be achieved by choosing right combination of CPU and memory intensive applications to the platform. Thus, high level of statistical multiplexing is pursued. This may sound as an easy task. However, this is a dynamic optimization problem that might be very hard to solve. The cloud scheduling optimization is a NP-hard problem, that might be solvable in a polynomial time but there is no guarantee of it [108]. Hence, the simulation approach taken by Krzywda et al. [13] is actually a sound solution for saving costs. The large scale simulation and scenario analysis of workloads may reveal ways to optimize the platform, thus, to avoid unnecessary hardware purchases.

6.3 Strategic Implications

Although the Telco Cloud seems to be superior on many ways compared to traditional platforms, more research need to be done so that all consequences are understood thoroughly. During the research, issues such as cyber security, system simplicity and overall usability due to software bugs and standardization were discovered. Any of these are worth of another research. Meaning, while the Telco Cloud platform is looking as a promising technology platform for telecommunications services, incumbents should proceed with caution. Especially lack of standardization should be seen as a risk. When these words of warnings are noticed, telecommunications providers are urged to boldly start the learning process that will eventually merge the telecommunications, internet and cloud service models. This approach is needed when the 5G mobile services are introduced early 2020s.

A typical incumbent telecommunications operator has tens or hundreds of different services that are still using traditional application dedicated platforms. The change from a present mode of operation to future mode of operations is going to take several years. However, the Telco Cloud gives financial motivations for operators to carry out a transition. The learning cost of the new model will be significant for first movers and those companies should proceed by using coherent strategic actions to avoid aberrations. Industry standards are going to eventually drive the technology to a dominant design, which is going to ease late-adopters.

Deployment of a Telco Cloud platform brings several strategic implications. An operator has to choose whether to build a platform by itself or to buy the platform from outside. The traditional model emphasized buying from outside as a turn-key solution. The Telco Cloud platform can also be purchased as a ready-made solution if an operator choose so. An operator has options to collaborate with external party by partnering, using alliances or co-venturing. The position of an operator in the market and competition situation steer optimal setting. The alliance with a competitor might be a sound solution. This study does not take any position on these matters. Instead, the study urges stakeholders to clarify the most optimal setup for their business position.

7 Conclusions

This section concludes the study. First is presented a brief summary of the research, key findings and contributions of the study. Second, limitations of this study are discussed. Finally, suggestions for further research are given.

7.1 Key Findings and Contributions

The purpose of this study was to explore financial and managerial implications of the Telco Cloud platform from a telecommunications operator point of view. Three angles to the context exist. First, study aimed to find a definition for the Telco Cloud paradigm. Second, the cost structure of the Telco Cloud platform was studied. Third, the strategic implications were studied. Finnish major operator planning to implement a Telco Cloud platform was selected as a case company and several manager position persons were interviewed for acquiring information on the subject.

The research was carried out using empirical and explorative approach using a single case study method. The collected data was analysed using qualitative data analysis techniques. After items were conceptualized, the paradigm, processes and strategic implications were defined. From those, the cost structure was formed using the Activity-based Costing method.

The research revealed that the Telco Cloud paradigm is a rather new phenomena. The concept is heavily based on the cloud computing paradigm. However, the telecommunication industry has specific requirements, such as high availability and redundancy, that are increasing the level of qualification.

This study contributes a widened definition for the Telco Cloud concept, combining views of the fixed and mobile schools of thought. The proposed platform model has three main characteristics. (i) It utilizes high level of geographical distribution. (ii) The platform is based on computing capacity which utilizes virtualization and leverage automation on high level. (iii) The platform is used for services with high quality, performance and regulatory requirements.

> *How the Telco Cloud could change the cost structure of network service production?*

During the research, 13 different activities were defined for the cost structure. In the Telco Cloud model, two of those are directly allocated for a product as a direct cost, one is allocated using number of configuration items, five are allocated using number of applications as a driver and five are allocated using amount of memory assigned for an application. The structure shows that both fixed and variable cost activities exist. Nevertheless, the strong network effects can be seen in the cost structure. While the number of applications and nodes increase, the cost per application decreases radically. In the traditional model, all activities are direct costs for a product, thus, the network effects does not realize as such. The main difference between a traditional platform model and the Telco Cloud model is the efficient use of hardware assets in the Telco Cloud model.

Does dynamic allocation of resources bring any benefit for the cost structure?

The Telco Cloud cost level was estimated using expert estimates and compared to a traditional platform calculations. The cost model simulation was carried out. Used assumptions are setting the break-even point to seven applications, thus, if more applications than that exist, the Telco Cloud platform will be more cost-effective. More important than the exact number is the model how the costs develop. When the environment is small and just a few nodes for applications exist, the share of cloud development activity is dominating costs. When environment grows and number of nodes increases, the share of the cloud development activity decreases and the asset management activity becomes the dominant. Hence, the cost structure contains two phenomenon. First, when the platform grows, the costs are moving from fixed to variable. Second, the network effects are greatly reducing per application costs by sharing fixed costs among all applications in the platform. These make the Telco Cloud platform more cost-effective than traditional platforms.

What kind of application on-boarding process can be used for introducing network service provider's services to the Telco Cloud platform?

Several Telco Cloud deployment specific items were recognized and mapped to the strategic capability model during the research. The application on-boarding process can be seen as a competence for managing assets. The application on-boarding process has five steps. The pre-planning phase is tightly bound to strategic planning processes to identify and select which services, and thus applications, are to be on-boarded. Financial and technical feasibilities are also checked. The planning phase carries out requirement engineering process to design an implementation of the service in the cloud. The development phase cloudifies, develops and tests the application and carry out piloting. In the implementation phase the actual application is taken into use and integrated to other systems. Finally the operation phase ensures the continuity of services. The on-boarding process can be carried out using a traditional plan-driven project model or Agile methods.

The deployment guideline part of this thesis covered strategic implications that are categorized using the strategic capability model. Numerous important assets were identified during the research that can be leveraged, such as data centres, networks and services. On the competence area, several new knowledge and skills were identified that must be built along the Telco Cloud deployment. Two major knowledge areas exist, a software production in the cloud environment as a technical knowledge and second, the competence of managing multi-vendor-multi-service platforms as a management related knowledge.

Several areas of critical success factors were discovered during the research. In the process related factors, capacity planning, testing and validation activities are found to be important. In the organization related factors, functional instead of service oriented organization model, clear responsibilities between teams and knowledge development on organization and individual levels are considered critical. In cooperation factors, tight communication and cooperation between internal and external stakeholders are considered essentials.

7.2 Limitations of the Study

This study concentrates on financial and strategic implications. This selection is done mostly due to the problem questions in the case company. Thus, a technological and a social perspectives are mostly excluded. Furthermore, the telecommunications provider view point is selected. Thus, a customer or regulatory point of view is quite limited.

The regulative and legislative region chosen for this research is Finland due to main operational location of the case company. Thus, this research does not apply as such for other regions. A company that is applying this model elsewhere, needs to check if other directives that are more restrictive than mentioned in this study exist in a local regulation.

A qualitative research methodology combined with a single case study approach limits the ability to generalize results. The number of interviewees is rather small. By using a multi-case study combined with a quantitative approach could give more generalizable results.

To ensure that the results of the research are valid and accurate, appropriate quality control mechanisms was used during the research. While the reliability and validity are somewhat more straightforward to prove with numeric analysis and with repeating tests in quantitative research [109], in the qualitative research the case is not the same. According to Kirk and Miller [110], all scientific researches requires objectivity and in case of qualitative research the objectivity can be split into two components - reliability and validity.

The reliability can be understood so that if the research methods are reliable, the research procedure gives same results no matter when and how the research is carried out. Hence, there should be no accidental phenomena in the research that might disturb the results. On the other hand, the validity can be understood so that what is the extent of answers correctness. Hence, the research results should be interpreted and presented in a correct way. [110] However, according to Dey [89], it is mostly impractical to assume that the qualitative experiment could be replicated thoroughly. It would require excessive commitment of effort and resources.

An interview based research results are highly dependent on the persons that are interviewed. If the sample was taken differently, also the output from the interviews would be different. On the other hand, the extent of tacit knowledge that is known only by one person should be quite limited in the case company, thus the number of persons from the area ensured that the most relevant information was collected. Furthermore, the transcript of the interviews were kept on detailed level to ensure that all relevant information can be recalled when needed. In any case, the sample size is too small for any statistical analysis. However, as mentioned earlier, the objective of this study is to carry out an exploratory research and observe phenomena in a single setting so that areas of further research could be pin pointed.

7.3 Future Research

The current literature of the Telco Cloud area is still very narrow. The literature review indicates that the area is not researched very widely. The context should be studied from several different perspectives to get more paramount view, such as a customer, regulator or application provider view. Some suggestions are presented next.

Future studies should continue exploring different use cases for the Telco Cloud model. This study carried out a single case study research of the area. A multi-case study of the same area could be carried out to ensure that results are more generalizable. In particular, it should be analyzed from a quantitative perspective how different services are actually fitting to the platform.

Research within the area of the cost structure should be continued due to importance of economic efficiency of clouds for service providers. This study presents the cost structure proposal and simulated calculations to demonstrate the behaviour of it. However, this model is just an initial model and future studies should be continued to define more accurately those theoretical models behind the platform. Thus, a need exists to move from exploratory research to constructive and experimental research methods.

On the business related research opportunities, the Telco Cloud based MVNO deployment models should be studies in more detail. Current literature does not cover this at all. Especially the business models that the Telco Cloud enables for MNOs should be studied.

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A Telco Cloud Related Regulatory Directives

Table A.1: Telco Cloud related directives set by Finnish Communications Regulatory Authority

Number	*Description*
8 C/2010 M	Reliability and information security requirements for identification service providers and certification service providers offering qualified certificates
28 I/2014 M	Interoperability of communications networks and services
33 F/2014 M	Technical implementation and ensuring emergency traffic
53 B/2014 M	The obligation to retain identification data
54 B/2014 M	Resilience of communications networks and services
55 A/2014 M	Telecommunications operators' cost-accounting systems and system descriptions
56 A/2014 M	Audits of cost-accounting procedures in telecommunications companies
58 B/2014 M	The quality and universal service of communications networks and services
69/2014 M	The general obligation of declaration of companies in telecommunication, software, software as a service and pay television operations

B Background Information of the Interviewed Persons

Table B.1: Background information of interviewed persons

#	*Current position*	*Age*	*CP*	*CC*	*IN*	*Education*
P1	Lead Architect	40-50	0-2	20-30	20-30	MSc (tech)
P2	Lead Architect (Software)	30-35	2-5	2-5	2-5	MSc (tech)
P3	Purchase Manager	40-50	10-15	20-30	20-30	Engineer (communications)
P4	CTO	40-50	5-10	15-20	15-20	-
P5	Solution Manager	30-35	2-5	10-15	10-15	High school
P6	Service Manager	40-50	15-20	20-30	20-30	Engineer (communications)
P7	Service Manager	35-40	2-5	15-20	15-20	-
P8	Service Manager	35-40	2-5	5-10	15-20	Engineer (communications)

Legends:
CP = Years of experience in current position
CC = Years of experience in the company
IN = Years of experience in the industry

C Question Template for the Interviews

Objectives

Purpose of this study is to explore concepts of Telco Cloud and its cost structure and strategic implications. The results from interviews will be used as a base material for analysis.

Background

Title		Age	
Years of experience in this position		Years of experience in this company	
Years of experience in this industry		Education	

Questions

These questions forms a body for this interview. However, any related item can be discussed freely. There are several type of questions raised during the interview and it is acceptable and understandable that all questions cannot be answered by one individual interviewee.

General part

- How would you define the term "Cloud Service"?
- How would you define the term "Telco Cloud" or "Carrier Cloud"?
- What functional components compose Telco Cloud platform?

Financial aspects of the Telco Cloud?

- What kind of financial expenses these mentioned functions contain?
- What kind of drivers there are behind these factors? (for example number of customers of traffic volume, etc.)
- What is the relative share of personnel related costs in these components compared to other costs?
- What is the relative share of capital expenditure related costs in these components compared to other costs?
- Which of these personnel related activities can be automated?

Real world limitiations

- Considering EU wide market, do you see any threats or opportunities brought by national or EU wide regulators?
- Is there any legislative considerations you would like to elaborate?

Financial comparison of traditional and Telco Cloud production model?

- Is there some cost components that are present only in Telco Cloud platforms but not in traditional production model or vice versa?
- Could you elaborate what is cost difference between cloud based approach and traditional production model?

Business perspective

- If services like SMS and VoLTE (voice over LTE or IMS more generally) are considered, what are those critical success factors that Telco Cloud platform must meet to be able to fulfil adequate service level?

Strategy, personnel and processes

- What new knowledge must be built due to Telco Cloud platforms? Or is there any knowledge that can be retired?
- What kind of process can be applied to transfer traditional telco service to Telco Cloud environment?
- In what way a strategy planning and implementation processes should support emergence of capability?

D The NIST Definition of Cloud Computing

2. The NIST Definition of Cloud Computing

Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model is composed of five essential characteristics, three service models, and four deployment models.

Essential Characteristics:

On-demand self-service. A consumer can unilaterally provision computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction with each service provider.

Broad network access. Capabilities are available over the network and accessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms (e.g., mobile phones, tablets, laptops, and workstations).

Resource pooling. The provider's computing resources are pooled to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer demand. There is a sense of location independence in that the customer generally has no control or knowledge over the exact location of the provided resources but may be able to specify location at a higher level of abstraction (e.g., country, state, or datacenter). Examples of resources include storage, processing, memory, and network bandwidth.

Rapid elasticity. Capabilities can be elastically provisioned and released, in some cases automatically, to scale rapidly outward and inward commensurate with demand. To the consumer, the capabilities available for provisioning often appear to be unlimited and can be appropriated in any quantity at any time.

Measured service. Cloud systems automatically control and optimize resource use by leveraging a metering capability[1] at some level of abstraction appropriate to the type of service (e.g., storage, processing, bandwidth, and active user accounts). Resource usage can be monitored, controlled, and reported, providing transparency for both the provider and consumer of the utilized service.

Figure D.1: The NIST definition covers five angles for Cloud Computing paradigm

E Cost Level Calculations

The details for the cost level calculation are in this appendix. First is presented initial values for the calculations. Some of the values are from literature sources and those are referenced accordingly. Most of the values are estimated using experts' judgement method. Second, all equations that were used for calculations are presented.

Initial Values

Measuring values

Variable	*Value*	*Description*	*Source*
N_t	20 pcs	Servers per node	EJ
N_c	3 pcs	Servers reserved for the cloud layer per node	EJ
N_s	17 pcs	Servers reserved for the application capacity per node	EJ
N_{sw}	5 pcs	Network switches per node	EJ
N_{spare}	10 pcs	Servers reserved for a spare, testing and redundancy use on total level	EJ
N_{appl}	8 pcs	Average resource requirement per application converted to physical servers	EJ
N_{pers}	2 persons	Number of initial personnel in operational activities	EJ
$N_{newpers}$	10 nodes	New operational person recruited every Nth new node	EJ

Technical specification values

Variable	*Value*	*Description*	*Source*
P_s	400 W	Power consumption per server	
P_{sw}	60 W	Power consumption per network switch	
E_{pue}	2	Average data centre PUE value	

Financial values

Variable	*Value*	*Description*	*Source*
C_m	120 €	Cost of MWh electricity power	[111]
C_s	10 000 €	Average purchase price of a server	EJ
C_{sw}	10 000 €	Average purchase price of a network switch	EJ
C_{dc}	20 000 €	Average purchase price of a rack and cabling	EJ
D_s	5 years	Depreciation time of a server and a network switch hardware	EJ
C_w	900 €	Internal day price for specialist work	EJ
C_{cm}	120 €	Configuration management annual per unit software cost	EJ
C_{cl}	1300 €	Cloud layer software annual license and support costs per server	EJ

Time estimates for activities

Variable	*Value*	*Description*	*Source*
T_{hw}	5 workdays	Hardware installation: Time required to install a hardware for a new node	EJ
T_{cd}	320 workdays	Cloud development: Annual time required for the activity	EJ
T_{ca}	1 hour	Proactive management and Capacity management: Annual time required per physical server for the activities	EJ
T_{pl}	5 workdays	Platform specification management: Annual time required for the activity	EJ
T_{hr}	5 workdays	HR activities: Required annual work time per employee	EJ
T_{vm}	4 workdays	Vendor management and Internal communication: required annual work time per application	EJ

Legends: EJ = Experts' judgement is used for estimating the value for the variable

Equations

Table E.1: Equations used for cost calculations

Description	*Equation*
Total power consumption per node	$P_n = N_t P_s + N_{sw} P_{sw}$
Total electricity cost per node per year	$C_e = P_n C_m E_{pue}(365 * 24)$
Total node deployment cost (CAPEX)	$C_n = C_s N_t + C_{sw} N_{sw} + C_{dc}$
Asset management activity annual cost, hardware depreciations	$C_{am} = \frac{N_{nodecount} C_n}{D_s}$
Hardware installation activity annual cost	$C_{inst} = \frac{N_{nodecount} C_w T_{hw} D_s}{D_s}$
Cloud Development activity annual cost	$C_{cd} = C_w T_{cd}$
Configuration management annual cost	$C_{conf} = N_{nodecount} N_t C_{cm}$
Proactive management and Capacity management annual activity costs	$C_{capa} = N_{nodecount} N_t C_{ca}$
Server operations annual activity costs	$C_{hwops} = N_{nodecount} C_e$

Description	*Equation*
Software operations annual activity costs	$$C_{swops} = N_{nodecount} N_t C_{cl}$$
Platform specification management annual activity costs	$$C_{platform} = T_{pl} C_w$$
Human resource management annual activity costs	$$C_{hr} = T_{hr} C_w (N_{pers} + \frac{N_{nodecount}}{N_{newpers}})$$
Internal and external communication and Vendor Management activity costs	$$C_{comm} = T_{vm} C_w \frac{(N_s - N_{spare})}{N_{appl}}$$
The total annual cost	$$\begin{aligned} C_{total} &= C_{am} + C_{inst} + C_{cd} + C_{conf} + C_{capa} \\ &+ C_{hwops} + C_{swops} + C_{platform} \\ &+ C_{hr} + C_{comm} \end{aligned}$$

F Concept Analysis Network Diagram

ATLAS.ti application was used as a tool for coding all transcripts. Furthermore, relations between codes and categories were defined using same tool. Figure F.1 illustrates the analysis network diagram of all those categorized concepts and their relation.

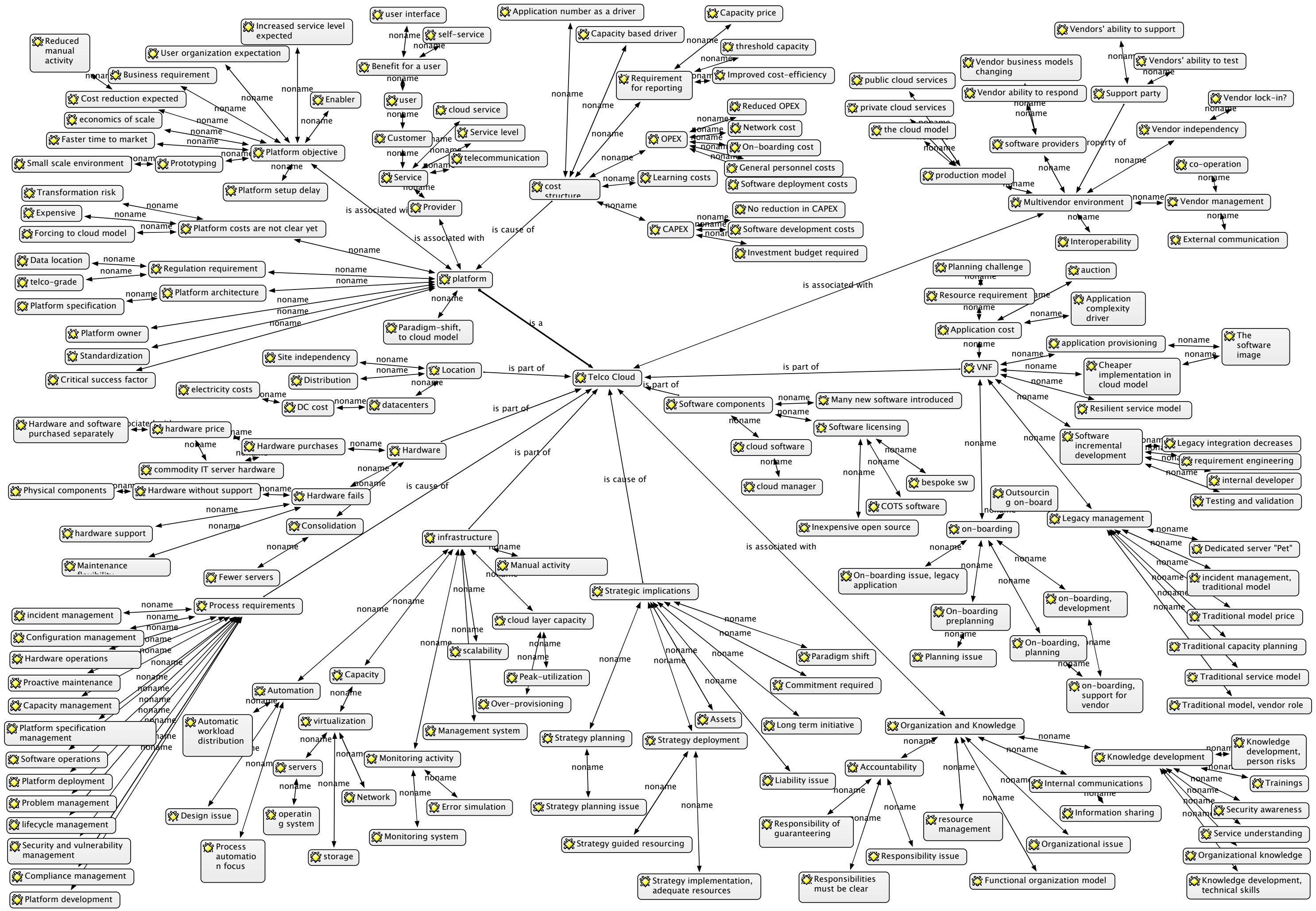

Figure F.1: Coded concepts and their relation were mapped into a network diagram.

G Interview Transcripts

All interview sessions were translated and transcripted after each session. This appendix contains all notes that were used for qualitative data analysis.

G.1 Cloud Service Paradigm

In the first part of the interviews, all interviewees were asked how they would define the term Cloud Service. The intention with this question was to get an overall view how people see the paradigm and the whole telecommunication industry.

> *[Clous service is a] service that can be provided to a subscriber or customer regardless of the location of a service provider or a customer. Requires minimum effort from a customer to take into use.* /P1

> *Service model in which a user does not need a physical access to the data center or own physical hardware. The service has a user interface that can be used for ordering the service. The payment type is a usage-based billing. The service is geographically distributed and a user does not have to care from where the service is produced, thus the service is location independent.* /P2

> *All internet based services.* /P4

> *Dynamic scalability is a big issue, additional capacity can be provisioned automatically. A single physical server does not contain any persistent data, a data should be distributed to several physical devices. All services should be clustered so that at any point of time any physical server can break without a major outage.* /P5

> *There are two kind of Cloud Services. First, Amazon and Google style public cloud services that are also open for consumer customers. Second, in telecommunication service provider world, private cloud services that are built on commodity IT server hardware. A hype is ongoing on this latter one right now, nevertheless, this is not actually a real cloud.* /P6

> *A service that is provided for an end-user, it is ease to use and capacity based. There might be many different kind of services provided. The service is not bound to any specific physical entity. The cloud service is a user perspective concept.* /P7

> *[The cloud service is] a service that contains high level of automation including charging and provisioning, scalability up and down, a user can maintain the service by itself. As an example infrastructure as a service is a cloud service. [There should be an] interoperability between multiple providers. A user can acquire a capacity from one provider and integrate it to its own infrastructure.* /P8

G.2 Telco Cloud Paradigm

In the second part, all interviewees were asked how they would define the term Telco Cloud. The intention with this question was to get an overall view how people see the paradigm and how they link it to the technology or business.

> *The Telco Cloud is a platform that uses the Cloud Service production model and meets requirements of a telecommunication service provider. The platform can be virtualized and distributed to locations that are optimal for provider's operations. The balancing of centralizing and distributing to some extent. The automation is on high level.* /P1
>
> *Telecommunication specific services are produced using a Cloud Service model.* /P2
>
> *The Telco Cloud is standardized capacity platform with generalized hardware solution.* /P3
>
> *Service infrastructure that is used for producing telecommunication services or functions that are produced using the Cloud Service model.* /P4
>
> *Capacity production model that is using the Cloud Service concept but only for services that are used in the telecommunication industry. Software images [that are used in the Telco Cloud] are ready made by software vendors. The platform might support hardware acceleration for a user plane traffic in packet switched networks.* /P5
>
> *Server farm that contains virtualized telecommunication services.* /P6
>
> *The Telco Cloud is a capacity platform that is compliant with requirements set by regulators for telecommunication services. Capacity can be transparently allocated for applications in telecommucation operations so that is follows all requirements set by FICORA, for example directive M54.* /P7
>
> *The Telco Cloud is representing a platform that is used for the virtualized mobile network element production and network function virtualization.* /P8

G.3 Structure of Telco Cloud

In the third part, all interviewees were asked what kind of structural components they can identify from the Telco Cloud. The intention with this question was to get a detailed picture of from what kind of structural levels and operations the Telco Cloud is forming.

Physical infrastructure [contains] servers, switches, storage, backbone network and datacenter connecting routers. Software components [are] virtualization, management software, OpenStack, orchestration that is controlling all individual applications, application lifecycle management, virtualized network functions (VNF), management components for controlling legacy application. Charging is not part of Telco Cloud, it is separate function. /P1

However, the Telco Cloud must be able to provide a charging information for charging process. The service provisioning is part of the Telco Cloud platform, capacity is provisioned to the cloud and must be able to taken into use by orchestration. /P1

Physical components [contain] datacenters, connections between sites, computing capacity - servers, maintenance of these and sustaining an ability to maintain. Software components [are] operating system, distribution of information systems [applications], cloud platform [components that are controlling dynamic loadbalancing between nodes and sites], actual service applications. /P2

Platforms must provide charging information for charging process but no requirement to charge by itself. Service provisioning must be able to resolve how workloads are distributed to nodes and it must provide adequate APIs for applications. /P2

Server hardware, virtualization layer, OpenStack, orchestration. /P3

Components like network, storage, computing capacity [servers], management tools to control the infrastructure, service life-cycle management, service provisioning. /P4

Controlling servers for orchestration, network and storage. Computing capacity [servers], network infrastructure. Orchestration is established part of the Telco Cloud but application provisioning is not. /P5

Hardware, virtualization layer, virtualized network functions [applications], cloud manager, orchestration layer, resource management, storage capacity and computing capacity. /P6

Network connections, computing capacity, storage capacity, management components related to automation, service layer. Service provisioning is part of automation. /P7

Physical components like servers, switches, routers, but no separate storage system because it is virtualized. /P8

Distribution is one of the starting points for developing hardware support cost structure. Traditionally a service has been centralized to the *one individual server and it has been treated like a pet. In case of malfunction, the server has been treated as long as the error has been fixed. In the Telco Cloud, the application should be distributed to several virtual servers and several sites so that in case of malfunction the service level is only degraded at most but no full outage. This leads to conclusion that in the future there is no need for separate hardware support contracts and all hardware can be purchased without expensive additional services. Broken hardware can be replaced by new one from the stock.* /P8

From licensing point of view, an open source model has been investigated. If commercial enterprise software are used, the cloud model is going to bring several layers to the stack. Server virtualization, storage virtualization, network virtualization and orchestration layers are bringing several support parties thus multiplied costs. If the overall solution will be expensive, it is not reasonable to use it [enterprise software] and thus open source alternatives are searched. /P8

However, this [the Telco Cloud] is going to require capability to integrate systems by ourselves. It requires more intense co-operation with software providers so that the platform can be acquired as supported and tested despite open source software is used. So far [software and hardware] vendors have been flexible and we have been able to co-create our Blue Prints. [To achieve this,] it requires certain knowledge. /P8

G.4 Financial Aspects of Telco Cloud

Financial aspects of the Telco Cloud were discussed in the fourth part of the interview. This part covered what kind of CAPEX and OPEX each previously mentioned component contain, what are those drivers behind each cost item that forces cost to increase or decrease and what work related activities are behind those. Furthermore, it was discussed which of the activities can be automated compared to the traditional production model and which of the activities have to be done by a human.

Capital expenses covers hardware purchases and software licenses like different layers of management softwares and openstack licenses. Also part of the installation costs can be considered as capital expenses because those can be activated in bookkeeping as an investment. Operating expenses cover electricity costs, data centre facility costs, hardware maintenance costs, leased line costs to remote sites, part of the installation costs and maintenance costs of different software components. /P1

Most of the costs are driven by required amount of capacity. When user plane traffic is traversing through the Telco Cloud platform, required amount of capacity will be much higher and it is causing much more costs. On the other hand, exactly equal amount of costs are reduced from legacy environments. From the control plane perspective, growth of *the user base, complex new applications or extended site distribution are increasing costs.* /P1

It is most probable that the Telco Cloud is not going to yield decreased capital expenses compared to traditional platforms. This is due to the fact that the busy hour of all services are more or less at the same time. Only if new applications can be utilized so that those are using a capacity on a quiet time or if traffic can be divided more evenly during the day. For example pre-delivering a content for a user can smooth the capacity requirements and interleave busy hours. However, this is not actually the Telco Cloud specific feature but rather a service application specific. /P1

[The Telco Cloud contains several manual activities] hardware installation, deployment and maintenance. Trainings, integration work to other systems. Planning activities when a new application is to be on-boarded to the Telco Cloud platform, containing requirement engineering, environmental requirements regarding virtualization. Also activities like integration, requirement engineering, managing legacy environments and lifecycle management, cloud maintenance, capacity management, incident management, repairing and geographical coverage planning are done manually. /P1

Furthermore, the software vendor management requires manual work done by a person. It contains creation of platform specification, thus requirements that an application must meet to be compliant with the platform. The team that is operating the platform is responsible for this specification and also responsible for communicating this specification to user organizations. The team also maintains a list of allowed and declined features or applications. The specification also covers definition of availability regions and allocations of capacity to different usage and security zones. The team is also responsible for having discussion with user organizations when things are novel. The goal is to just allocate capacity for an application and maintain it. However, this is going to take many years to happen. When an application is on-boarded, activities should be more or less just a maintenance of the application. If the automation fails, fault management activities should be started as soon as possible also from the platform perspective. /P1

Instead of thinking of what can be automated, the focus should be on that the automation is done at all. All kind of automation activities should be promoted. For example a scenario where DDoS attack initiates provisioning of several new virtual machines to fulfil capacity requirement. /P1

The important point is that the whole service from end to end should be brought into the Telco Cloud, not just small pieces. By doing this, the whole chain can be automated and the goal is much easier to achieve.

Especially if there is totally manual processes, all manual phases should be automated, thus, the focus is on process and service automation. /P1

Virtualization exposes benefits when there is certain critical mass reached. Thus, economics of scale is reached. Number of legacy integrations should be decreased. The number of applications are functioning as a catalyst. /P1

[Capital expenses cover] hardware costs. [Operating expenses cover] maintenance costs, a lifecycle maintenance, datacenter costs such as facilities, cooling, electricity, etc. Also software licenses on yearly or monthly recurring costs. Yet, personnel costs. /P2

Capacity meter drives the expansion of the platform by showing how much there is capacity available. Competition in the market might also be a driver in some cases. If some competitor is producing more cost efficiently services on the market, we have to react and drive costs down. This can be done by using auctions for hardware and software purchases. /P2

The amount and share of personnel costs is depending on the time frame that is used for analysis period. In the software layer, traditionally the goal is to make a big development in the beginning and small updates and a maintenance later on the life cycle. This hardly never realizes. The requirement engineering is in important role. It might turn in to situation where a maintenance and small incremental updates are causing most of the life cycle costs and the initial development is just a small part of the costs. This might be specially true if considering applications that must be kept on the customer requirement level. Of course, the case might change application by application. /P2

I don't have exact knowledge of how big share the hardware costs actually are of the total but feeling is that the cloud layer should be kept modern. We should follow our time and produce new features continuously so that we can compete with our competitors by at least equal feature set services. Software development costs could be relatively large compared to hardware costs, thus the hardware costs are relatively small. /P2

There are many activities that can be automated when compared to the traditional service production. The goal is the end-to-end automation. For example, operating system installations automatically. However, hardware installations cannot be automated - but almost everything else. /P2

[Capital expenses] server hardware, licenses like openstack, orchestration layer software, data center capacity like facilities and racks, integration work that can be activated in the bookkeeping. [Operating expenses] all miscellaneous costs like electricity, fault repair activity and platform operation. /P3

This cost structure should be well understood and communicated to stakeholders so that they understand into what kind of environment applications are going. Previously vendors provided working solution as a turnkey solution, the cost was easy to predict and forecast when traffic volumes were growing. From the user organization perspective the goal is the same in the Telco Cloud. The traditional model contained application price, hardware price, operation system and licenses as one tested solution with the fixed price tag. The Telco Cloud is not actually bringing that many new components but we have to find out the structure and capacity requirements by ourselves. Actually there was no requirement [in the traditional model] to have a person to handle measuring and life cycle management because the vendor has taken care of that. Now we have to take the responsibility and we have to calculate the costs by ourselves and we have to also carry the responsibility. /P3

The cost driver is based on the utilization of the platform and the number of application in the platform. We need to exceed some critical mass. The volume will decrease produced unit cost. It is hard to predict how the number of subscribers are going to reflect to actual server capacity requirements such as memory and CPU. At this phase only control plane and application layers are going to the Telco Cloud, not a user plane traffic. By keeping the user plane out of the Telco Cloud wider geographical distribution of nodes is enabled. However, the previous objective was to consolidate data centres. This is contradicting with the Telco Cloud's distribution strategy. We have to balance between the consolidation and distribution. If there is enough capacity saving potential available on some geographical area, then there is a reason to use the distributed model, otherwise centralized. The distribution can save network transmission costs. However, the distribution is causing a slack to capacity on every site, thus, the overall utilization will be lower. On the other hand, centralization reduces manual work by removing extra sites' support, spare-part and problems. Furthermore, regulators requirement of the TL1 directive is quite strict and causes big investments - there should be very good reason to utilize many regional sites. /P3

Our previous internal operating model was - vendor is responsible of everything. When problems occur, this is very cost effective way. When a new software release was to be installed, the vendor tested it and guaranteed that it works in our environment. Now in this new [Telco Cloud] model, we are taking huge responsibility. There is one vendor that is providing the cloud orchestration layer and we are putting all our bets on that. On the other hand, we have a major role when coordinating all different software vendors. We have to use more resources than earlier on this. For now on, we have to assume that a software vendor does not have exactly same kind of testing environment what is our production environment. So we have to test it by ourselves. This generates more *work. Especially in problem cases the challenge is to identify the problem source. Who is responsible for fixing?* /P3

We cannot yet say what will be the actual cost level of used hardware and software, it is too early. However, hardware is surprisingly expensive and it is looking like that it is challenging to create a cost-effective solution. It is too early to say if one single application is better to implement using the Telco Cloud or a traditional model. In the beginning, all costs are distributed to only a few applications and this [Telco Cloud] will be more expensive than traditional platforms. We have to see this as a long term investment. We are paying learning costs. This is a big challenge for us. This is new to everyone. Standardization is not ready yet, there are no interfaces between vendors - one might compare this [Telco Cloud] project to building of family house project where one contractor is using inch meter and another one is using centimeter. However, in this case vendors are working voluntary and hoping that the OpenStack forum is releasing more concrete specification one day. Now we are in a self-guided development process that none is leading. Successors will be those who are now a part of this learning process and are able to bring own insights to the development process. /P3

There should be a clear model for capacity measuring and cost structures in our company. The model should be application based, for example starting costs plus recurring costs. An application vendor should be able to tell capacity requirements based on our business drivers. /P3

In the beginning we have to make big investments. After that, it is more like a capacity management. Individual services are causing capacity requirements to change, so we need a forecasting model. /P4

There might be services which life time is very short. A dedicated platform for such a service would not be feasible at all. So the Telco Cloud is going to enable a production of this kind of services. When more new services are added, the average unit cost should decrease. However, we should get to the model where we don't have to discuss about investments when considering new applications to the Telco Cloud. For example when you want to move workloads to Amazon cloud service, you don't have to discuss about investments. It is purely operators internal issue how capacity is allocated to services and how forecasting is done, especially when we start from zero. /P4

In the beginning we need some initial investment so that we get going. All subsequent additions are done by modules. In our case the timing of services to the Telco Cloud is not yet clear and to prevent over investing additions should be quite small. /P4

There are many tasks that can be automated, but there are some that cannot be automated. A database service is hard to automatize. If we *need a database server, then we proceed with the traditional model. If the service is critical, it is also safer to bring additional capacity online manually. For example the DNS service is such that you don't want to mess with that, you want to make manual check and then bring a new server online.* /P5

Onboarding a new application also requires some manual work. It is too early to say exact number but in one project there was a few persons that used a couple of hundred hours to onboard one application. We are now in the learning phase. When we have got the knowledge we can estimate what this time will be in the future. /P5

Each application onboarding initiative must be compared to the traditional way of producing the service. It must be considered at which target level of the automation is pursued. The more cloud features are targeted, the more time it is going to take. /P5

[Capital expenses] hardware purchase costs, virtualization license costs, NFV application purchase cost. [Operating expenses] hardware maintenance costs, electricity, facility costs, virtualization maintenance costs, openstack costs. Personnel costs like hardware operations, virtualization and operating system maintenance. NFV application maintenance costs. Application maintenance. /P6

It should be noted that there are several OSS modules for different layers in a stack, like monitoring and management systems. The cloud manager, platform and application are going to each require own OSS stack. /P6

The biggest item that is driving costs up or down is traffic directly volume and indirectly customer base. /P6

There are a few activities that cannot be automated in the cloud model. Designing process is more challenging in the cloud environment. In a traditional environment the capacity planning is easier in the beginning. But when the platform is up and running, scaling is easier in the Telco Cloud. Purpose of the cloud platform is to simplify maintenance processes - how this is going to happen is not clear yet. General purpose hardware can be used in a cloud. This is simplifying operating systems operations. In the application level, almost nothing is going to change. The maintenance activity is like in the traditional environment. One new task is to identify security treats and vulnerabilities, and patching of those. It will be harder in the cloud than in a traditional environment. /P6

[Capital expenses] hardware purchase cost, automation layer's license cost including virtualization. [In operating expenses] there are several layers where costs are accumulating. Monitoring, service automation

and orchestration all use different software products, so there will be multiple cost sources. /P7

The costs are mainly driven by the capacity usage. Cost of an automation is not clear yet. The software can be acquired as a boxed from a vendor, it can be bespoke software or we can hire coders to do it for us - or we can even use open source software to do the task. The cost is different in all these cases. In any case, continuous development is required so that a service automation can be advanced further, including the configuration management. One big source of costs is licenses which are using capacity based pricing. /P7

Manual work have to be done in a hardware installation and hardware maintenance. Also life-cycle upgrades to the automation software are done manually. Yet, there are continuously small maintenance tasks and development of monitoring practices that are also causing manual work. /P7

Our current test environment contains a set of hardware and orchestration software. The purchase price was split equally between these two. If enterprise level software was used it costs more, the total software stack might cost as high as 70 percent of the whole platform purchase price. There are actually no major differences compared to traditional platforms in the cost structure. Biggest difference is an automation that adds some software, hence more costs. The benefit is that when the platform is up and running, it can produce faster with fewer persons compared to traditional platforms where all work was done manually. /P8

In the traditional model one physical server produces one network function. In the virtualized cloud model, one physical server can run several network functions concurrently, so there will be fewer servers to be maintained. Maintenance of a server consumes time. When there is uniform hardware platform used, it is much easier to maintain. Also operating system installations can be automatized. The workload can be located in any site and capacity can be added on the fly without causing outages [to the service]. When the platform is functioning as planned it does not require continuous control. Maintenance activities can be shared to wider time frames, also faults are not so critical. Services has to be designed as resilient as possible toward hardware faults. This brings flexibility to maintenance tasks. /P8

The hardware vendor independence is one of the targets. This enables us to purchase the hardware from any vendor we want to keep purchase costs on adequate level. On the other hand, there are a lot of software in a stack. All software are different. There are orchestration software that is running the automation and then there is a lot of service applications. If we think just the platform engine software, all kind of scripts must be done. /P8

Provisioning of new services can be automated to the zero touch level. Also capacity monitoring of existing services and provisioning of an extra capacity when needed can be automated. On the other hand, automation can tear down any excess capacity that is not needed to save resources. Automation covers also charging and invoicing. In the case of malfunction, automation can transfer the workload to an alternative node. /P8

G.5 Comparison of Traditional and Telco Cloud models

In the fifth part, all interviewees were asked how the Telco Cloud platform makes difference compared to traditional telecommunication service platforms. The intention with this question was to get a detailed picture of how the cost structure of a service is changing when it is transferred from a traditional service platforms to the Telco Cloud platform.

[The Telco Cloud] project has made an assumption that the expected benefit will be reduced operating expenses due to an extensive automation. This also requires that a system integration has to be done simpler. In the future there will be no vendor specific hardware to be maintained, there is a need for spare parts only for a small number of different devices, support channels to several vendors. If we can build a virtualized service chain then we can make the deployment of services much simpler. /P1

It is not expected that the Telco Cloud could reduce significantly capital expenses. Operating expense reduction is use case dependent. Average expectation is 20 percent efficiency improvement. However, highly dependent on the volume and amount of realized manual work has an affect. /P1

The goal is to take advantage of the virtualization. For example CPU utilization improvement compared to a traditional platform. Over-provisioning with a dynamic capacity management and assumption that usage spikes are not on the same time in different services. [The Telco Cloud] requires thinking work, planning and knowledge of that how services can be executed in the same environment taking into account for example security constraints. If there are multiple services in a platform the system is more complex than a single service platform. /P2

The traditional platform model might be actually an obstacle to establish a new service due to large initial investments and a big risk. In a cloud environment this barrier is significantly reduced and new services can be started and prototyped with much lower risk. However, it is very hard to estimate cost difference. /P2

If several different applications can be utilized in the platform so that dynamic load-balancing can be used, even 30 percent saving in hardware costs. On the other hand, cost introduced by the orchestration, integration *work, vendor management, and capacity required by the orchestration itself are causing extra costs. It is still hard to forecast the benefit because project is in so early phase. Estimate would be that if there are less than ten applications we cannot identify any savings. If there is tens or hundred different applications in different life cycle phases we might assume that some benefit can be realized. It is going to take many years any way.* /P3

Any specific cost saving target has not been defined yet. We have to observe the [Telco Cloud] platform still so that we could manage it in the future. Investment efficiency has to be improved in new growth services, thus cost level [of the Telco Cloud] cannot be higher than the current level. When we are planning to introduce a new service to the [Telco Cloud] platform, we have to be capable to calculate a business case. One aspect of deploying the Telco Cloud is to improve investment utilization on overall level. /P4

For example in the traditional platform model, the SMS service is one rack of hardware and the MMS is one rack of hardware. Now vendors are introducing basic server virtualization to these racks and they are talking of this dedicated virtualized capacity as a Telco Cloud. /P4

A traditional platform contains dedicated rack of hardware for a service containing all necessary to run the service, including the application. The solution is provided as a turnkey solution, containing hardware, operating system and application. This model has resulted data centres that contain service dedicated racks from many different vendors. In the Telco Cloud, a vendor provides only virtualization image that can be installed to the generic environment. /P5

[When Telco Cloud is deployed] the telecommunication service production can move from service dedicated racks to the centralized model. /P5

To be able to learn differences between a traditional and the new model, we want to be part of this building phase so that we can observe how external vendors are building an environment. The challenge is that, at the moment, practically there is no standardization available for hardware platform. Current standards are on so high level that those does not guide any implementation item, except high level architecture and concept levels. The idea is that we provide the platform for software providers and they provide applications that comply with the specification. /P5

[When moving from a traditional to the Telco Cloud,] a dedicated hardware is removed and is replaced with a shared hardware. New features that should be also built into the cloud are the data backup and restore functions. The issue that must be still resolved is intra-site connectivity. Currently a vendor uses significant amount of time to configure internal and external networks of a service. In the future we should have a ready

made specification and vendors must implement that by the book. In the Telco Cloud, things cannot be taken for granted, designing is much more complicated. /P6

The voice over LTE trial project was actually more expensive when it was done using the Telco Cloud model than what it was if done traditionally. For this project we had to purchase dedicated test hardware anyway. However, all applications are going to virtualized world eventually so the number of applications in a cloud will be big and it is expected that a cost per application will come down. /P6

All vendors are trying to get into that position where all revenue comes from a software. We might also have a possibility to arrange auctions for the software. For example in the IMS architecture we could pick each subsystem separately from the vendor who provides it most cost-efficiently. The vision is that when we have a standard platform, a software auction will be easier. Also implementation cost will be cheaper when a hardware is already in place. /P6

The Telco Cloud can provide a faster time to market and we can try different things. For example we can test several elements concurrently. Also implementation time get shorter. /P6

In a traditional model we buy the capacity with a fixed price X. The hardware is very specialised and very tightly bound to the application. In the future, a price of the hardware will drop significantly and a cost of automation licenses is the new component. In the future, we are paying for application software and application capacities which are running on the virtualized platform. /P7

We have to be careful with the automation. We very easily build a multilayer licensing structure where we are paying for many overlapping components. If each vendor brings their own automation software to the system it is surprisingly costly very quickly. /P7

Previously we have bought a whole platform as a turnkey solution. From now on we are buying the software as a turnkey solution and the hardware as a turnkey solution. Two separate entities. /P8

It is possible that there will be some cost difference between a traditional and the Telco Cloud production models. Especially in the mobile production there is potential. Virtualization alone can bring consolidation benefits. The ability to scale down enables an efficiency improvement. However, dynamic scaling requires several different applications. Separate dedicated service platforms does not support dynamic scaling because each platform has to be measured by their peak utilization. By combining these, we can achieve benefits. /P8

G.6 External Forces

The roles of Finnish regulators and the Finnish legislation in the domain of the Telco Cloud were discussed in the sixth part. Furthermore, responsibility issues between several stakeholders were discussed. The intention with these questions was to get an overview of what kind of external treats and opportunities there are that must be taken into account.

> *The FICORA does not necessarily introduce any new directives. Distribution [in the Telco Cloud] actually is going to improve the usability of a service and might ease the regulatory pressure. For example, in a 5G world we are actually moving very rapidly closer to the customer by introducing NFV capabilities to mobile sites. This improves an overall quality and a network can be optimized also. However this requires a software licensing model from vendors which allows subscriber based capacity licensing that can be freely located to different sites.* /P1

> *The current Finnish legislation does not allow production of the telecommunication services from off-shore or even near-shore locations. For example telecommunications identification information cannot be handled from abroad. This is not a Telco Cloud specific issue, but it has to be taken into account when planning services that are spanning across country borders. If some information must be located near a customer, but is somehow relocated to the cloud that also contains an information from other sources, it might trigger some kind of cumulative threshold if there is too much sensitive information in one place.* /P2

> *The situation [in the Telco Cloud] is a new because there is no single stakeholder that would take an overall responsibility of the solution. We have to develop required knowledge to the purchasing tasks and we have to practice where the responsibility borders between vendors reside. We have to be transparent and open in communication toward application vendors so that vendors understand that we are running their software in a cloud environment. Responsibilities between vendors have to be agreed and we have to do a coordination work more that before.* /P2

> *I don't have exact knowledge on regulatory issues. However, contractual liabilities between stakeholders is another issue. In a traditional model we have big contractual liability toward a vendor because the vendor is willing to take responsibility of a service quality. When we are moving to the Telco Cloud model the situation changes. The hardware and software stack is in small pieces and there are also many small contracts with several vendors. There is no external party that is taking full responsibility so contractual liability is also smaller.* /P3

> *It is unlikely that the regulator would introduce any new directives due to the Telco Cloud. If it did, there would be some problem in the market to*

fix. It [the Telco Cloud] may actually make easier to comply with existing directives - service resilience and redundancy in the long run. /P4

If the platform is well distributed then it should be noted where the actual information is located. Especially for international operator this might be a risk if not taken into account. Also information security must be taken seriously. /P4

There are many indirect directives that are forcing to do [a service production] in certain way. [For example] location of a data and how it is managed. There is a common trend to reduce regulations. It is interesting to see how it ends if we find a way to enter to the same kind of situation than other purely internet based service providers have which are not regulated at all. /P4

It will be challenging to be compliant with security directives in the future [with the Telco Cloud]. Dedicated service platforms have been easier to handle. Giving a specific access right or check who has an access when the system is highly layered will be much harder. Everything will be in the same box in the future. For example, a task - list all persons that have an access to the system so that they can stop the service. Not trivial any more. /P6

If there were many major incidents that are caused by the Telco Cloud it is possible that regulator will reactively ask us if there is a need for a new regulation to keep quality on the adequate level. Also a cyber security might be one issue. /P6

Currently traditional platforms have been provided by one vendor. I don't know yet if there will be challenges to handle multi-vendor platforms. Currently a vendor declines if the platform does not follow their reference architecture. It is possible that we [as a company] take more responsibility but it is possible that the top management does not want that. There should be always someone to lean on in case of a problem. In the future we must keep tight control of vendors and we must have clear responsible coordinator to ensure that the responsibility does not run away too far. /P6

Regulations have to change. Current directives are talking about a device level redundancy and in the future redundancy will be on a software level. [For example,] if there is N number of instances and one fails, the workload transfers automatically elsewhere on the software level. It is not clear if current regulation's redundancy specification can be complied with this one. We have to open a discussion with regulators to ensure in the beginning that the solution is compliant and how those directives should be understood. This has a major impact on costs. /P7

Applications will be on much critical role and it is likely that this layer will be part of the regulation. Applications must be redundant and regu-

lator might intervene how this redundancy should be implemented. Currently regulator says how electricity, cooling, physical security should be done. When an intelligence is moving to upper layers it is likely that applications will be on that list too. /P7

The potential cost saving won't be so big that regulator would lower the maximum transit pricing. The cost of human work will be same as now. Current mechanism to define the maximum transit pricing does not put pressure to decrease prices. /P7

G.7 Business Perspective

In the seventh part, it was discussed which are those critical factors that must be in such a condition that businesses can rely on the Telco Cloud platform. Services such as SMS and VoLTE/IMS were considered as reference services. The intention with this question was to get an overall list of items that should be checked when the service is transferred to the production in the Telco Cloud.

A geographical distribution due to TL1 requirement. Legacy requirements apply also. An application must be able to replicate by itself and be redundant by design. Application logging might be more the application level issue but not a platform level issue. The cloud model is complex and there are several parties in installation activities, testing should be done thoroughly and through the testing we should validate the environment that replacement of a component does not break the system. And while we have defined the platform by ourselves, we have to take responsibility of it. /P1

An update management is another topic. A vendor has to be able to do patching fast enough. There has to be a process for the application management. The organization model of one team per service is changing to functional teams. /P1

The development direction in contractual liabilities, that one big liability is transforming to many smaller liabilities, is not necessarily good thing but actually we have no choices. The size of liability is highly dependent on the size of deal with a vendor. /P1

Resiliency must be ensured so that when some component breaks we can test that the service still works. Sites must be independent from each other - another site must be able to take-over the workload when another goes down. The capacity must be planned to survive failure situations. /P2

Ensuring service availability and redundancy. It is balancing between what redundancy features are implemented in a software, in a cloud and what in a platform level. The requirement level is hard. Organizational knowledge must be developed to the level where specialists understand the *service better. [For example,] a specialist with an IT background does not necessarily understand requirements of telecommunication services like load balancing, signaling and so on. For example after a network outage if there are one million users that are registering to the network, is there enough capacity to sustain this kind of peaks. Capacity planning of overload situations must also be planned beforehand. We have to agree who is responsible of a measuring, usability, load balancing and synchronization.* /P3

Security is also one critical factor. What kind of privilege level is granted for external application management service providers? It have to be planned beforehand how we protect other applications from one faulty application. One cannot jeopardize other applications - some kind of encapsulation must be implemented. /P3

[The Telco Cloud] must be able to show transparently benefits that was promised. It is easy to talk about speed and flexibility. /P4

The critical success factor is that the expected service level is already set. The quality level of legacy services set the minimum. It cannot go worse. A user experience must be improved. The change is a risk. /P4

If services are transformed widely to the Telco Cloud platform, businesses need to be supported to take advantage of it. We must also be able to compete with traditional internet based service providers on our traditional [telecommunication] markets. We must find same kind of [internet based] methods to produce competitive services. /P4

[The Telco cloud brings] speed and just in time [for application implementations]. [Also] prototyping and possibility to scale up and down fast. Current model requires from 9 to 12 months to set up a platform. /P4

A traditional telco is proven [technology] and in the new model, there is a risk that usability degrades or uncertainty grows. However, the target state brings more reliability, scalability for capacity and improved user experience. /P4

The system should be kept as simple as possible. Vendors are offering their own automation tools but we have intentionally limited deployment of those so that complexity does not raise needlessly. The goal is to make a HA in the application layer and put a trust on the platform level as little as possible. HA requirements must be design on a service basis. /P5

Cooperation between organizations are becoming a critical factor. Much more tight collaboration than in a traditional model. We have to agree who is communicating with whom and how responsibilities are divided. We have to build a layered thinking model. If something happens we have to know who must to act. Capacity management has to be fully *working and hopefully automatic. Some kind of high level cloud manager is needed that can for example prevent other services to fail in case of overload situation.* /P6

[The Telco Cloud should] be able to shorten the required time to market. /P6

It is normal that hardware failures happen and applications have to be able to survive those. /P6

Service testing has to be in a good shape. The same for monitoring and metering. There are several error situations in the traditional IT world that does not affect services so dramatically and are forgiven. Those errors are becoming a critical in the telecommunication service area. Errors in a network link, micro bursts and congestions must be managed and an alarm should be raised. /P7

Automation should work well and application testing should be done properly. We have to simulate different kind of error situations so that we can ensure that the service is functioning as planned. From the platform perspective the critical is monitoring and the ability to monitor right things. Specifically the application level testing is a part of the on-boarding process. /P7

The cost level should not exceed the cost level of a traditional model. It should be ensured that there are enough capacity available especially in congestion situations like Christmas or New Year. /P7

A transport network must be very solid and resilient. Usability of packet networks should be on equal level than on circuit switched networks. Complexity of the system must be managed. All software contain bugs. There will be many layers of software in the stack. When these softwares are functioning as a series of systems, the total usability might be degraded more than anticipated. Frequency of failures is increasing. Customers will see this as a degraded service level if redundancy does not work. /P8

G.8 Knowledge, Processes and Strategy

In the eighth and the last part were discussed what kind of knowledge development and application on-boarding processes must exist when transforming to the Telco Cloud. Strategy related issues were also discussed briefly. The intention with these questions was to get an overview of what kind of new knowledge, organization roles, intra- and inter organizational collaboration bodies and strategic planning and implementation tools are required to support the development and operations of the Telco Cloud platform.

OpenStack is one of the major technological areas that need to be developed on knowledge side. In user organizations, the knowledge of differences between a traditional model and a virtualized model, yet so that *actual differences between platforms can be hidden. Users want more information, so there is a need for bulletins for the Telco Cloud. However, we don't want to stack the burden to user organizations. We want to communicate the concept of what we are talking about, operating model and different organizations involved this [Telco Cloud].* /P1

Especially in the maintenance organization there is a need for improving Openstack and SDN knowledge. Also automation objectives, challenges in on-boarding and software skills and knowledge must be improved. Now there is a few persons that know the environment very well - their knowledge must be shared to the operational staff. Responsibility for service operations is in our own hands but we have to use our vendors when there is a problem. We have to improve the knowledge of our application vendor chain. In this early phase, we have to put more stake on this [the Telco Cloud project] so that when a new application is to be purchased we know if it is going to the Telco Cloud or not. /P1

There should be pre-made calculations of [the Telco Cloud] costs that can be compared to a traditional model costs when doing the strategy planning. Now we want to favour OpenStack capability when new network functions are acquired. If application is OpenStack ready, it tells that something must be on the right track. Then we can choose what to do, either to purchase a service dedicated platform or use the Telco Cloud. If the Telco Cloud is built, no one wants to leave it empty. A lot of workload is wanted to be located to the platform, also workloads from traditional platforms. In the pilot phase the investment can be relatively small. /P1

In the strategy implementation phase it is important that there are enough resources available so personnel budget need to be inplace. There has to be a vision which applications are to be on-boarded so that clear and transparent roadmap can be created and forecast of the target where we are going during the strategy period. It is important to collect a service life-cycle information from user organizations so that the information can be collected for what platforms are to be renewed during the next year and what new applications are to be installed. And on the other hand, if there is an application that needs a geographical distribution beyond existing, this requirement is also important to identify. /P1

Knowledge that breaks technological boundaries are becoming important. A technology based narrow focused knowledge development is old-fashioned and it is not enough anymore. Cloud platforms are mostly a software. The border between a hardware and a software in the knowledge has to be faded. Coders have to understand a hardware and hardware maintainers have to understand softwares. For example if there is a hardware failure, maintainer has to be able to understand how to maintain the platform without service outage. Software coder has to understand the platform to be able to optimize the application for that environment. Only a part *of the applications can function efficiently in a cloud world. There is a pet and cattle allegory. Pets are those servers that require constant control. Cattle are those servers that can be destroyed at any time and rebuilt when needed. Only a cattle type services are suitable to the cloud. Currently this way of thinking is not yet widely enough used.* /P2

The on-boarding process starts with a planning phase. Then features are developed, results are measured if the target was met - and testing in a small scale production environment. It is a good practice to take pilot customers to the testing phase. This testing phase is monitored very closely how load is developing. Measuring parameters like normal levels and threshold values have to be defined. If anything problematic occurs then return to previous state. You have to be very careful with telecommunications services. /P2

This on-boarding process changes the way of thinking of the code. The design have to be thought using a pet and a cattle principle. Updates to the software are carried out so that a totally new server is deployed with a new software, added to the pool and then the old server is destroyed. The services can be seen as a pool of resources. On the other hand, there has to be a location for a permanent data storage. Actually this is quite challenging in this new cloud model. There has to be some kind of non-volatile storage media available in each site for this kind of data storing. For example an object storage that provides standardized API for a software layer. It is highly dependent what kind of application it is if it needs a storage space at all. /P2

The testing procedure does not change much compared to the traditional model. The platform is harmonic, same kind of servers. If a new server is brought into existing service there has to be a way to test it. If the platform itself does not change physically there is no exact need for testing. If there are platform changes then it is good to test. /P2

Strategy planning and deployment activities should observe how synergies can be found from different applications and needs. Two individual project can benefit if a part of those are done together, a traditional way is to done everything separately. Some may find the traditional once per year strategy planning too coarse. Better model would be some kind of rolling strategy planning where activities could be planned when needed. In a yearly cycle normal way to estimate things is to exaggerate so that there is no need to add later on. A rolling planning model would bring more realistic situation. Currently the software requirement engineering and effort estimation are very challenging. /P2

Strategy planning should guide quite strictly how resources and more specifically people's time is allocated to different projects. All applications are not moving [to Telco Cloud] instantly. It takes time and requires learning. To develop competencies, investments are required. It *is not enough to discuss in strategy planning phase of different targets, it is important that the actual deployment targets are put into practice. Concrete competence development tools are good and should be used. We [as a company] already have a wide range of services. Different [business] units are going in the different life cycle phase with their services and architectures. It is challenging to put everything into the same picture. It requires patience. The Telco Cloud is strongly growing at the moment. It is understood in various ways. Many vendors are working their own business models and it brings additional degree of difficulty. Big potential is to change the setting while operators have major role in standardization. Open standardization should be preserved and there should not emerge vendor specific solutions and definitions. Keeping the openness is important.* /P4

Furthermore, there are some differences how the Telco Cloud differ technology management vice from traditional platforms. At the moment one modern network can produce a wide variety of services for many kind of customers. This same concept needs to be copied to the service side so that all those underlying platforms can be consolidated. This leads to improved investment efficiency, avoidance of idling and increased utilization. However, this requires optimal services that are different enough so that dynamic advantage can be achieved. The benefit is realized when the capacity is not metered by the peak utilization but different busy hours get interleaved. Furthermore, when a platform and an application layers are separated, the life cycle management becomes more efficient. A service can be short or long lived and still the underlying infrastructure remain up to date. /P4

To build a Telco Cloud capability, a lot of time is required. It is not a fast process. It takes big actions, commitment and vision on all level. Currently there is a potential set up, themes are widely discussed in the strategy and it is introduced to the company wide architecture steering. There is also a top management support for this. /P4

The requirement for competence development is inevitable. The change is coming. There has to be people with right skill sets. When service strategies are created, it should be planned so that the Telco Cloud model is utilized. This is a big change. This requires approaching issues from many different angles. The infrastructure must be built step by step forward and the knowledge get built gradually on the way. /P4

We are going to need software persons who are working with OpenStack closely. Those persons have to work across organizational boundaries. OpenStack is not well developed technology. Gartner has stated that if a company is going to deploy OpenStack techology, the company must accept the fact that a lot of work hours are required and it is worked out mainly as a lab project. Currently we would not have time to work this *out if the vendor was not helping us. Question is that are we in a vendor lock-in situation.* /P5

The process for on-boarding the new software starts with a survey if the application actually is such that it can be orchestrated. There are very few applications that is such that it can be orchestrated out of the box. None of the application vendors has taken a position how the orchestration is to be done. There is not yet support from application vendors so it might be quite a big project in the future. If an external vendor does the on-boarding it costs significant amount of money. When using a traditional platform model the platform is taking a care of HA, but in Openstack environment the application must take care of redundancy. Each compute node is a single individual entity with its local hard drives. The Telco Cloud is a collection of stand-alone servers. Hence, the requirement follows that the data cannot be in one server only. The data must be distributed to several servers. /P5

There is very little standardization work done yet. When we ask a vendor about best practice models they turn the question back to us that how we want to implement the solution. I got the feeling that the vendor is doing this first time. It seems that there is no standardization done yet. We are driving the specification work quite much. On practical level we must develop methods on the fly. However, those actual NFV functions are quite standard based after all. /P5

Though there is the strategy deployment project going on it seems that we are doing this project only when we have time from other duties. This is still an experimental project for roughly five years. After that if we find this [Telco Cloud] model as a non functioning we can change the technology. /P5

I may raise a couple of other issues. The overall picture is that this [Openstack] is still very young technology. Vendors are doing things first times. For example during the implementation we found out that the IPv6 feature was not supported at all despite they had promised so. It will come within six months. Seconds, the major QEMU KVM security vulnerability was totally ignored by the vendor. We had to ask when they are going to fix it. It also is going to take months before they can fix it. All these security issues must be kept on the wall. All personnel must be aware of security risks and genuinely interested of security topics, so that when deviation happens it can be recognized and reacted properly. /P5

Technologies that must be mastered well are operating systems, especially Linux, IP networking and virtualization. However, these are quite same as in traditional platforms. Knowledge that is not needed [in the Telco Cloud] is vendor specific hardware such as DX exchanges. Applications *will be vendor specifics also in the future and the way of using software remains the same. There is no major change happening here.* /P6

[When transferring services to the Telco Cloud] the major issue that must be resolved is understanding of who is doing and what. Also the organization model that is running clouds need to be sorted out. Responsibilities between departments must be clear. As a use case, Nokia DX ATCA software is quite easy to transfer to the cloud model - according to the vendor. If any user plane centric function is tried to be on-boarded, things will be challenging. Control plane is much easier. /P6

The strategy deployment model supports emergence of the Telco Cloud. If there is a software that needs hardware renewal, it must be very well justified if a traditional model must be used. The cloud model is preferred. Investment budget is in place so no problem there. One case example was the VoLTE pilot some time ago. The actual pilot environment did cost nearly 40 percent more than what it was costed using dedicated model. The company is willing to invest so that we can learn doing new things and building capabilities. /P6

There certainly are knowledge areas that need to be developed. There must be someone who has comprehensive understanding of the application and platform cooperation. The understanding must be raised to the adequate level that in problem situations we can overcome any issue as fast as possible and even anticipate those problems beforehand by observing how applications are behaving. Knowledge of handling vendors and cooperation between operations staff and vendors must be developed. In the future we must find a model for tight integration between vendor and operations. The old traditional AMS model when we put a ticket in and wait a day is not feasible anymore. We must have within minutes reaction time in problems. Yet, we have to develop how we manage the big picture. On the operational level one of the biggest issues is monitoring capability and knowledge to identify relevant information from incoming data streams. We are now entering into new grey zone. For example, it is easy to identify broken hard disk but we have to get same kind of capability to virtualization and network functions. There will be a lot of new components and we surely don't understand all those yet. /P7

The on-boarding process is highly dependent on organizational understanding of what requirements there are from the platform level to the application level. The knowledge transfer and information sharing is a critical issue. When this is on the right track we can start trusting that we are able to produce services maturely. It is not possible to on-board legacy applications [to the Telco Cloud], those just does not work right. There must be understanding what we are doing and what it takes to get working solution. There also have to be brave enough people to stop the on-boarding process if it seems that an application does not fit [to the

Telco Cloud]. There might be some applications and vendors that can be handled so that we just hand out the specification document and say that please implement this. But it is our task to identify those applications. At the first place we need that specification document which describes platform's requirements. If a vendor needs more hand in hand style approach, the Telco Cloud technology manager has to be in the on-boarding process to ensure that vendor does the right thing. In this case we have to have an active role in the development phase. Furthermore, we have to have testing environment that can be used for a debugging and software assurance before deployment. /P7

There should be more specialists in the strategy planning phase to contribute real-life realities. Those persons would also build bridges between today's situation and target situation. There should be some technology evangelists in the company that would promote actively visions where the world and technologies are going. Those persons should be also listened. On the other hand, there certainly is a business related strategy planning areas that don't need this kind of persons. At the moment we are in a such phase that it is really important to understand how technologies are affecting businesses and so that we could understand, we have to find options. The Telco Cloud as such is a good start, but there is a need for a more generic cloud strategy that could be linked to the bigger picture. If we just build the Telco Cloud, there will be many good application areas that are left outside. The Telco Cloud, by itself, does not need more attention that anything else. The key here is that an overall strategy would cover all these in well-balanced way. Second in strategy area - roles of different platforms must be understood. This is mainly an internal communication and PR issue. There should be an owner in the company level that would guide and steer where to go. It would also function as a link between application user organizations. /P7

The most important knowledge that must be developed is Linux skills. Networking staff must learn servers and software, at the same time also to forget old way of doing networking services. Server staff must learn more of networking though. In the future, server and networking people should walk hand in hand in development projects. In a cloud, almost everything is software based. /P8

The on-boarding process is highly service dependent. The application must be compatible with the cloud model. Meaning, the application should be scaled by replicating new machines. This covers also redundancy. A redundant node is made by bringing more virtual machines to the pool. HA is done in the application level, not in the platform level. The on-boarding should be done along the normal life cycle phases. /P8

The strategy deployment process should bring some tools to promote understanding of what are those differences to build the Telco Cloud compared to traditional platforms. /P8